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OF THE

ROYAL ASTRONOMICAL SOCIETY.

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WILLIAM HUGGINS, ESQ., F.R.S., President, in the Chair.

Robert C. Carrington, Esq., Indian Marine Survey, Calcutta;

Alexander Davidson, Esq., Addison Lodge, Ridgway Place, Wimbledon;

Thomas Gregory, Esq., Merchants' College, Blackpool;

Lieut. F. W. Jarrad, R.N., Deputy Superintendent, Indian Marine Survey; and

Dr. A. K. Rollit, LL.B., B.A., Sheriff of Hull, President of the Royal Institution, Hull, 18 Trinity House Lane, Hull;

were balloted for and duly elected Fellows of the Society.

Mr. David Gill's Expedition to Ascension; Correspondence and Reports.

Downing Street, August 20, 1877.

MY LORD,—I am directed by the Earl of Carnarvon to transmit to you, with reference to your letter to Mr. Lowther of the 9th June, a copy of a despatch from the Governor of St. Helena relating to the possibility of taking astronomical observations on that island.

I am, my Lord, your Lordship's obedient servant,

JOHN BRAMSTON.

Lord Lindsay, M.P.

Governor Janisch to the Earl of Carnarvon.

(COPY.)

[No. 33.] *St. Helena, July* 7, 1877.

MY LORD,—I have the honour to report that Mr. D. Gill, referred to in your lordship's despatch No. 73, arrived at this island on the 1st instant, and it gave me much pleasure to afford him all the assistance I could.

2. It is a matter of great regret to me that his arrangements require him to proceed to Ascension for the proposed observations, instead of making them at St. Helena, the position of which is so perfectly adapted to the observation of *Mars* in its present southern declination.

3. Mr. Gill himself shares in this regret, and informs me that it was at first intended to select St. Helena for the purpose, and that the alteration in the plan was caused by a mistaken supposition that the atmosphere of this island was too cloudy to be favourable. This opinion was founded upon published meteorological observations made at Longwood; and it was not until his arrival here that Mr. Gill became aware, from his own observations, that the clouds which prevail at Longwood and other elevated positions to windward do not usually extend to James' Town and the leeward side of the island.

4. I have mentioned this circumstance in the hope that, looking to the approaching transit of *Venus*, a similar mistake may not prevent astronomers from availing themselves of the advantages offered by the position of this island.

I have &c.,

(Signed) Hud. R. Janisch.

Right Honorable the Earl of Carnarvon, &c. &c. &c.

Mr. Gill's Reports: Preliminary Report, dated August 15, 1877.*

I beg to forward to you, as President of the Royal Astronomical Society, the following report of my doings up to the present date.

Accompanied by my wife, I left London on the 14th June, taking with me the chronometers of the expedition, received the same day from Greenwich, and the following day at noon sailed from Dartmouth, and reached St. Helena on the morning of Sunday, the 1st July. Instruments and baggage were safely landed; and, thanks to a despatch from Lord Carnarvon to the Governor, procured through the kindness of Lord Lindsay, comfortable lodgings were ready for us, and accommodation for the more delicate instruments was provided in the Castle. The heavy packages, houses, &c., were stored by Messrs. Solomon, Moss, Gideon, & Co., agents for the Donald Currie line of steamers. Captain S. T. Olliver, R.A., kindly offered the services of some of his gunners to carry such instruments as I desired to the site of Johnstone's Observatory (Ladder Hill)—now the Artillery and Engineer mess-room; and, as I wished to make a chronometric connection between Ascension and St. Helena, I gladly availed myself of this offer. On Monday (July 2) the chronometers and reflecting circle were conveyed there; and altitudes of the Sun,

* To prevent a possible misunderstanding of expressions in these Reports, it is right to mention that the Expedition was undertaken only in part at the costs of the Royal Astronomical Society.—Ed.

morning and evening, were observed for time. Similar observations were repeated frequently during my stay on the island; the chronometers were wound and intercompared daily.

During my stay on the island, I visited Halley's Mount, and discovered what undoubtedly has been the site of Halley's Observatory. An oriented foundation of a building still exists, overgrown by ironwood scrub (called on the island wild pepper), and near the observatory are evidently the remains of a quarry, whence the stones for its erection have been taken.

Halley does not appear to have selected the best site on the island as to meteorological conditions; at least, in the present day Ladder Hill is very much better.

To windward the island rises very abruptly nearly to its greatest height, and it is a very curious and interesting sight to watch the mountain ridge from a point near Diana's Peak, when the dew-point of the approaching trade current is a little below that of the temperature of the ridge.

Out to windward the sky is clear and blue, and so it remains over Sandy Bay (the low land between the ridge and the sea). Twenty or thirty yards below the crest of the ridge, and perhaps a hundred yards seawards, the cloud suddenly forms like a grey mist, rolls over the crest, and becomes thicker and blacker, depositing itself in rain as it passes over the high land, and then, as it descends to the lower land, it dissipates in the higher temperature, and over Ladder Hill all is again clear blue sky.

I found that Sabine's observations made at Longwood (nearly the most cloudy part of the island) did not at all represent the amount of cloud at Ladder Hill; and the reasons will be evident from the illustration I have given.

As night after night showed clear blue sky, and conditions generally favourable for astronomical purposes, I could not but regret that my pledges to the Society prevented my settling down here without incurring the further anxiety and risk of transhipping so much delicate apparatus. This regret was much increased by the great sympathy and assistance I should have received from the Governor. He is himself an enthusiastic amateur in astronomy, would have afforded every assistance in erecting the Observatory, and would himself have undertaken the time determinations.

On the afternoon of July 10 we left St. Helena, and on the morning of July 13 reached Ascension.* Two flags exhibited at the pier-head indicated that "double rollers" were in and that landing was dangerous; but we learned that preparations had been made to receive ourselves and baggage on board H.M. Supply Ship *The Industry*. Fortunately this became unnecessary, the rollers abated somewhat, we got safely ashore, our goods being placed in a large lighter, ready to be landed when the rollers would permit, and this was fortunately accomplished the

* It will be necessary to procure the Admiralty Chart of Ascension (surveyed by Lieut. Bedford, R.N.), 1838, to understand this Report.

same evening. During the day I was busy inquiring as to a site. In answer to my questions about cloud, the reply of everyone was: "There is far too little of that; you will have no trouble from cloud," and so forth.

I knew that whatever cloud we might expect would probably be chiefly due to Green Mountain; it was generally cloud-capped, and so it was that day. I was told that often it was so, but that this cap of cloud simply remained there and did not affect the purity of the rest of the sky.

The house provided for our accommodation (photograph 1 enclosed) is situated in "Garrison" (George Town on the map), and "Garrison," excepting the Sanatorium "up the Green Mountain," is the only inhabited part of the island. To go "up the mountain" amongst the clouds was of course absurd; to get any point to windward* or south of Green Mountain I was told was impossible, because the lava was impassable by land, and there were no landing-places on the island where instruments could be put ashore excepting the pier-head and Comfortless Cove to the north of Garrison.

Garrison appeared to be, then, the only site, and exactly opposite our house—not twenty yards from our door—is what is called the "croquet ground," a large levelled space paved with concrete; and here I had all the baggage carted on the morning of July 14.

Notwithstanding a kind invitation from Captain Phillimore to spend a few days with him till we could get our house in order, we took up house at once, so as to be on the spot; and with the assistance of some blue-jackets and marine artificers, the Observatory (photograph 2) was erected in a couple of days.

At the end of five days all the instruments were established in perfect adjustment, with a distant meridian mark to the south, and a mark in focus of a long focus-lens as collimator to the north for the transit. The whole was as complete and comfortable as could be desired. For the first few nights after our arrival the sky was beautifully clear; but hardly were the instruments adjusted when cloudy weather set in and completely upset all my hopes of obtaining a series of observations of *Ariadne*.

After some vain attempts I was reluctantly compelled to give up the *Ariadne* investigation, and commenced the triangulation of the *Mars* stars of comparison, and for some days with considerable success.

Though the evenings and mornings were cloudy, still it was possible for some time to secure observations not far from the zenith, and in this way, by much labour and watching I was able to go over most of the principal triangulations once. Matters however got worse and worse, and I began to fear that some persistent cause was at work, and that the opinions I had gathered as to the weather were not trustworthy.

* Being in the trade-wind, this is S.E.

Everyone declared that such a period of cloud had never been before observed; but it appeared to me that much of it was due to local causes. I observed frequently that whilst we had a band of cloud across the zenith, the horizon to north and south, particularly to south, was often clear.

The band of cloud undoubtedly came from Green Mountain, was carried over Garrison and out to sea; the point was, would it be possible to get south of this cloud, and, if possible, could an observatory be erected and maintained there?

Captain Phillimore, while warning me of the difficulties attending any change in the site of the Observatory, volunteered in the kindest manner to assist in every possible way, not only in any change I might desire to make, but also in the search of a site. The night of Monday, July 30, was typical of many that had gone before, and, that I might not lose any opportunity of observing that might occur, my wife volunteered to make the necessary observations. Accompanied by two servants, she set off at 10 P.M. and walked as far south as possible, making simultaneous observations with me at previously arranged instants. These observations were continued from 10 P.M. to 3 A.M. at each half-hour, and from these I was enabled to draw definite conclusions as to the cause and position of the cloud band.

These conclusions were briefly as follows:—

1. In certain conditions of the trade-wind the effect of the Green Mountain resembles the effect of introducing a lump of soft clay in a stream of clear water—a broad band of cloud is produced, which passes over the island in the direction of the wind. The cloud begins somewhat to windward of the peak.

2. The south limit of this stream of cloud passes nearly vertically over the south limit of "South-West Plain," about as far as "Round Hill." To clear this cloud it was evident that a point near the south limit of the island must be occupied, and also pretty far east, so that the cloud which may form windward of Green Mountain shall subtend the smallest possible angle.

The following day Captain Phillimore and I set out to explore. From South Gannet Hill we saw the small bay shown (unnamed) on the chart, due south of Saddle Crater, and one of the watercourses seemed to render it possible to reach this bay from the land side. It is impossible to describe the extraordinary character of this lava, but I hope to send some photographs of it by next mail; except in the beds of watercourses, it is quite impassable—the lava is so rugged and so sharp. Locally it is called "clinker." We reached the bay, and, after close examination, Captain Phillimore believed instruments could be landed on a smooth day. At the extreme north-east corner of the bay there is a little sandy beach, and the projecting rocks seemed entirely to protect it from the swell from the south-east. The official report in the hands of the Admiralty states that there is *no* landing place here, and the bay is not in sight of any signal station. Captain Phillimore was convinced of the justness of his conclusions, and undertook the

responsibility of the landing, and when my friend Lieutenant Hammich, commanding H.M.S. *Cygnet*, undertook to give me Kroomen to carry the heliometer tube by land, I resolved to dismantle the Observatory the following day. That night (July 31) I obtained a fine set of evening and morning observations of *Mars* and comparison stars, and was strongly tempted by kind advisers to let well alone, and take my chance of some clear nights rather than incur the risk, anxiety, and labour of another transport and erection. I had, however, already weighed all these chances, and, accordingly, when the men arrived on Wednesday morning, we set to work, and by the same evening, with the aid of a considerable force of men, all the instruments and houses were dismounted, repacked, and stowed in a large lighter moored near the quay. At sunrise next morning (Thursday, August 2), the lighter and some small boats were towed round by a steam tug to our bay, now called Mars Bay. The day was unusually fine, and, under the skilful personal superintendence of Captain Phillimore, all the instruments, houses, &c. were safely landed without a scratch. Friday and Saturday were occupied in re-erecting the Observatories and instruments, and on Saturday evening the heliometer was adjusted, and, but for excessive personal fatigue, I might have obtained morning observations of *Mars*. On Sunday, August 5, I obtained good evening and morning observations of *Mars*.

During the day of the 5th August I found that, without some special arrangements, life would be unsupportable at Mars Bay, from flies, sandbugs, and other insects. I therefore returned by land (walking over the clinker) to Garrison, to procure carbolic acid, mosquito curtains, and other protections from insects, and returned the same night to make observations.

I had the misfortune to strain a tendon in my knee-joint (an old weakness), and reached Mars Bay, feeling very ill, and in considerable pain.

The night was fine, but when I attempted to observe I could not see, and was unable to stand. I sent for a doctor next day, who came and had me carried over the clinker by men, and conveyed to Garrison, where he found I was knocked up by exposure, anxiety, and fatigue, and was suffering from a local fever called the "Roller Fever." He promised I should be well in three days if I would place myself in his hands. Accordingly, on Friday the 10th, I was able to return to work, and secured morning observations of *Mars*. On Saturday the 11th we had rain, and after the early evening persistent cloud. I shall add at the end of this report what weather we have up till mail goes.

I can only now say that I have an Observatory here complete in all points. Complete arrangements have been made for the regular supply of food and water from Garrison, and such provision made for my own comfort as, I believe, will enable me to live without much loss of health. The best possible site in the island, in an astronomical point of view, has been secured, and we

can now only wait for such weather as the trade-wind brings. The observations secured seem to be good; at least, the observer, in making them, has the satisfactory feeling that he is measuring a well-defined satisfactory object. The character of the definition is much more crisp and sharp, and the images are more steady here than in Garrison; and I look forward to a satisfactory determination of the parallax, if Providence sends me health and fine weather.

The following observations of *α Centauri* may be interesting to astronomers who are engaged on the orbit of that interesting binary.

α Centauri.

1877.	P. Angle. ° ′	Weight.	
July 22	69 25	½	Distance *about* 2″·0 or 2″·1.
27	80 35	2	I defer a more exact value till I have completed a reinvestigation of the screw.
28	75 17	1	
Aug. 5	80 33	2	

August 15.

Two additional morning observations of *Mars*, and one additional evening observation, have been secured: that is, in all, four evening and five morning observations. Much has been done within the past two days to render life comfortable; roads have been made, and the neighbouring patches of lava-dust covered with sand.

The following additional observation of *α Centauri* was made last night:—

1877.	P. Angle.	Weight.
Aug. 14	80° 42′	4

The weather shows signs of improvement.

The observations recently secured would have been lost in Garrison.

I trust the Society will find it possible to convey their thanks to Captain Phillimore for his great and successful exertions on behalf of the expedition.

The Observatory, Mars Bay,
Ascension, August 15, 1877.

Second Report, dated September 4, 1877.

By the mail which should leave September 5 (the day of *Mars'* opposition) I beg to forward the following report of the progress of the Society's Expedition.

In my last report I described the reasons which induced me

to dismantle the Observatory in Garrison and re-erect it on its present site.

The necessity for this step has been abundantly proved by the result, and whereas on very few occasions would measures of any kind have been possible in Garrison, a considerable number have been secured here.

The amount of cloud has been unusually great, and this has made the labour of watching very excessive.

By dint of constant watching *Mars* has been observed since August 10 whenever visible between 20° and 75° zenith distance, except on two occasions, when the definition was unsatisfactory and it was not thought advisable to make observations.

Both these occasions were in the evening, and observations in satisfactory atmospheric conditions were secured at a later hour. The accompanying table will give a pretty accurate idea of the observations secured. Only those are entered which are satisfactory and complete, and capable of being used in a parallax determination.

The definition, with the exceptions above mentioned, has been exceedingly steady and sharp, and the conditions of temperature are even more satisfactory than I had anticipated.

The table attached gives the reading of the external thermometer before and after each set of evening and morning observations, and it will be seen on examination that not only is the temperature range between evening and morning confined to a little more than 1° F., but the extreme range throughout the whole series is less than 3° F. Though the observations are so arranged that a difference in temperature between the evening and morning observations can produce no systematic error in the final result, yet there is no doubt that this remarkable uniformity will tend to diminish the final probable error.

The Observatories and dwelling tents are now connected by good paths, and these and the patches of volcanic dust have been covered by rough-grained sand (particles of shell) from the beach. The supply of food and provisions has been systematically arranged. Thanks to the tents in store from the Ashantee Expedition, our tent accommodation is excellent, and generally, as to comfort and health, all is as well as need be. The ample time observations (generally made by day) are reduced, and their results, together with duplicates of the heliometer observations for preservation, will be forwarded by next mail. For the past few days there has been but little of the usual trade-wind, and the island has been covered by nearly continual cloud during the night; thus no observations have been possible during the important period since August 31, except during a break in the cloud for two hours on the evening of September 2. This change causes me much anxiety, occurring as it does at so critical a juncture. I earnestly trust the weather may prove favourable during the remaining half of the opposition, and that I may thus be able to report the entire success of the expedition.

The accompanying photographs will illustrate the arrangement of the Observatory.

Mars Bay, Ascension Island,
September 4, 1877.

Third Report, dated October 5, 1877.

I am happy to report the success of the *Mars* observations, or at least their success so far as it is possible to judge without complete reduction.

Satisfactory observations have been secured on 32 evenings and 25 mornings, during which series the distance of the planet has been measured from 22 different stars of comparison, the whole embracing 327 complete measures of distance, of which 194 belong to the evening and 133 to the morning observations. A *complete measure* involves four bisections, eliminating index error and planet diameter, so that 1,408 bisections will be employed in the complete discussion of the observations. The rainy season, which I feared (as stated in my last report), actually set in, and entirely prevented observations from September 11 to September 15, and indeed more or less from September 11 to the end of the month, but most fortunately was preceded by exceptionally fine weather during the important period September 4 to September 11.

This latter period was of extreme importance, because—

1° September 5 was the day of opposition, and the planet also passed within 2′ of arc of the comparison star *g*. A very long series of this important appulse was obtained.

2° During the period September 5 to 11 the parallax was near its maximum, and also the planet was always nearly in the line joining the comparison stars *e* and *g*. This pair of stars has been used as the standard distance in the triangulation, and is therefore the best determined distance in the triangulation; the position angle of the line joining these stars differs only 5° from 90°, the direction of maximum diurnal displacement.

3° The position angle of greatest phase was during this period nearly at right angles to the direction *e–g*, and the maximum phase was very small; hence, along the line *e–g* the limbs were actually without phase.

For my own part I would willingly have undertaken the labour and anxiety of the expedition for the chances of this opportunity alone, and in its successful issue I hope the Society will not regret their liberality in promoting the expedition.

By this mail I send:

1. A copy of all the observations of *Mars*, with a short explanatory preface; this for preservation in the event of any accident to myself or to the original observations.

2. An account of the time determinations and definitive table of their results.
3. An account of the chronometers and discussion of the definitive daily error of the observing chronometer, with table of this error for every day of the *Mars* observations.
4. Observations for errors of the micrometer screw.
5. A note on the geographical position of the Observatory at Mars Bay.

By next mail I hope to send a complete copy of the observations made in triangulating the stars of comparison, together with a chart showing the plan of the triangulation.

The following Observatories have promised co-operation in the work of making meridian observations of the comparison stars :—

Greenwich.

Paris.

Pulkowa.

Several German Observatories, through Dr. Auwers.

Cordoba (Dr. Gould).

Cambridge, Mass.

Ann Arbor, Michigan (also extra-meridian observations).

Mr. Hartnup has also promised extra-meridian observations at Liverpool.

I have also sent lists of the comparison stars and requests for co-operation to the following Observatories, from which no replies have as yet been received :—

Washington.

Cape of Good Hope.

*Melbourne.

Sydney.

Lord Lindsay has also promised observations at Dun Echt, so far as these will not interfere with the declination observations of *Mars*, and Dr. Ball at Dublin has also promised co-operation, conditionally on the state of health of his assistant Mr. Benton.

I hope that the result of these observations, combined with the heliometric triangulation, will give places of the comparison stars accurate to 1-10th of a second of arc at least, so that the differential equations resulting from the measures of distance may all be combined, neglecting the errors of the star places.

I regret that my last report (now enclosed) by an unfortu-

* *Sept.* 10, 1877.—Since the above Report was written, the mail has arrived, bringing a letter from Mr. Ellery, to say that the *Mars* comparison stars will be observed at the Melbourne Observatory.

nate combination of circumstances missed the last mail, together with the rest of my month's correspondence. This accident is the more to be regretted, that some requests for special observations will, I fear, be too late now to be attended to so fully as I feel sure they would otherwise have been.

My health has somewhat suffered from the prolonged strain of the past two months, and I propose to-morrow to go "up the mountain" for a week's holiday and cool fresh air, and then to return to the completion of the triangulation of the *Mars* stars of comparison and the observations of *Melpomene*, when I hope the present period of cloudy weather will be past.*

Mars Bay, Ascension Island,
October 5, 1877.

On the Inferences for the Value of Mean Solar Parallax and other Elements deducible from the Telescopic Observations of the Transit of Venus, 1874, *December* 8, *which were made in the British Expedition for the Observation of that Transit.* By Sir G. B. Airy, K.C.B., Astronomer Royal.

The Society are aware that, in response to a question in the House of Commons, a Report of the results as to the value of the Mean Solar Parallax derived from the telescopic observations made in the British Expedition for observing the late Transit of *Venus* was prepared and printed in the past summer, and is now on sale with other parliamentary documents. Although all important points were fully treated in that Report, several minor matters were necessarily deferred; some which, in the first instance, did not present themselves for consideration; and some which, under pressure of time, it was difficult to examine. I propose, in the present Paper, to supplement the Parliamentary Paper; to describe the process there pursued up to the point of treatment of equations, omitting, however, the somewhat voluminous details; and to resume the equations and to treat them in what appears to be the legitimate form; presenting the results which, I think, necessarily follow from the British telescopic observations. At some future time, I trust, these observations, and these reductions (with any variations which time may suggest) in a more orderly form, and with the additional inferences to be derived from the photographic operations, will be printed under the auspices of the British Government.

Acting as official superintendent, and under official responsibility, I have examined and approved every part of the operation. But I am bound to state that the most important discrimination of classes of observations, the scrutiny of individual observations, the organisation of an efficient computing staff, and

* The statements of the observations of *Mars* which form part of these Reports are printed p. 17 *et seq.*—Ed.

the general maintenance of order in the calculations, are due to Captain G. L. Tupman, R.M.A., head of the British Expedition for observing the Transit of *Venus*.

The printed paper to which I have alluded specifies the elements of geographical position and the evidence for accuracy of longitude at each of the stations. It contains also the description of the classes of observations to which the observers had attached definite times. At ingress it was usually possible to distinguish three classes of recorded observation, which, for convenience, were marked α, β, γ, of which β appeared to be most certain. At egress the classes (in the opposite order as regarded change of angular interval between the limbs) were δ, ε, ζ, η; ε or ζ appeared to correspond with β (I think ε the better, but ζ was more frequently noted), and η corresponded vaguely with α. The observations of all these classes are carefully distinguished and fully exhibited.

The order of reductions then adopted was as follows:—The observations were first divided into the two great groups of Ingress and Egress, which were kept separate to the end. Then the group of Ingress was divided into different pairs of comparison (accelerated by parallax at Sandwich Islands with retarded at Kerguelen; accelerated at Sandwich Islands with retarded at New Zealand; retarded at New Zealand with retarded at Rodriguez; retarded at New Zealand with retarded at Kerguelen). And the group of Egress was similarly divided into pairs (retarded at Mokattam and Suez with retarded at Rodriguez; retarded at Mokattam and Suez with accelerated at Kerguelen; retarded at Thebes (Luxor) with retarded at Rodriguez; retarded at Thebes with accelerated at Kerguelen). And in each of the pairs for Ingress, the α, the β, the γ, of one station was compared separately with the α, the β, the γ, of the other; and in each pair for Egress, the δ, the ε, the ζ, of one station was compared separately with the δ, the ε, the ζ, of the other.

The reduction of a comparison of observations made at two stations was thus completed. Adhering to the first steps in my Paper printed in the *Monthly Notice* of 1874, December 8, the registered times of all observations were converted into Greenwich Sidereal Times; and with these, and with a table of Tabular Places and Parallaxes which has long since been circulated, the Tabular Geocentric Places and Tabular Local Parallaxes were prepared, and the apparent Local Tabular Distance between the centres of the Sun and *Venus*, affected in each case by a symbolical multiple n of the effect of increasing Tabular Parallax by $\frac{1}{100}$ part, was computed for every observation. This apparent local distance between centres, thus computed for Greenwich time of observed contact of limbs, ought to agree with the simple tabular assumed difference of semidiameters; and, for each

station, an equation was formed, asserting this equality, affected only by errors in the places and in the semidiameters of the Sun and planet. The effects of these latter errors were assumed to be equal at the observations made at the two stations, and therefore disappeared in the comparison of the two equations, leaving as an unknown term the multiple of n. The numerical value of n being found from this equation, and the assumed numerical value of the Sun's mean parallax adopted in the calculation being $8''{\cdot}950$, the true value as found from these observations is $8''{\cdot}950 \times \left(1+\frac{n}{100}\right)$.

After carefully considering all the results for n, and combining them with proper weights, the values obtained for Mean Solar Parallax were the following:

By Ingress, $8''{\cdot}739$, weight 10·46;
By Egress, $8''{\cdot}847$, weight 2·53;
General Result, $8''{\cdot}760$.

In order to insure general correctness of the result, and also to ascertain the values of the errors in the tabular places of the Sun and *Venus*, and to show how all may be affected by possible errors of observation &c., I have now thought it best to form equations strictly in the manner described in my paper of 1874, December 8, and to treat the whole mass of equations, both for Ingress and for Egress, in one united assemblage, by the method proper for combination of equations.

To prepare for this operation it appeared desirable, if possible, to reduce the times of all the observations at Ingress to the times which would have been adopted by the observers for phase β, and to reduce all at Egress to those for phase ζ. For this purpose comparisons were made of all observations which could connect the different phenomena. The results obtained were

The observation α is *earlier* than β by $24^s{\cdot}22$; {and the angular distance between centres of Sun and planet is *greater* at α than at β .} by $0''{\cdot}78$.

The observation γ is *later* than β by $20^s{\cdot}17$; {and the angular distance is *less* at γ than at β .} by $0''{\cdot}64$.

The observation δ is *earlier* than ζ by $48^s{\cdot}4$; {and the angular distance is *less* at δ than at ζ .} by $1''{\cdot}63$.

The observation ϵ is *earlier* than ζ by $21^s{\cdot}0$; {and the angular distance is *less* at ϵ than at ζ .} by $0''{\cdot}72$.

The observation η is *later* than ζ by $72^s{\cdot}1$; {and the angular distance is *greater* at η than at ζ .} by $2''{\cdot}41$.

No use is made of the observations η.

The tabular apparent distances between the limbs of the Sun and *Venus*, having been computed for the registered time of every observation, were then affected with these corrections, and were considered to represent the true tabular distances of limbs, subject to the assumption that the phase β for Ingress and the phase ζ for Egress, intended to correspond to apparent contact of the true limbs of the Sun and *Venus*, may require corrections which I shall call β and ζ; that the tabular semidiameters of the Sun and planet require the corrections δR and δr, and their difference therefore requires the correction $\delta R - \delta r$, which I shall call ρ; and that the excesses of the Right Ascension and North Polar Distance of *Venus* above those for the Sun require the corrections δ.RA and δ.NPD. There may be a clock-error or error of longitude affecting all the times of observation at one station, and therefore all the distances of limbs at one station, by the same quantity, different for different stations: for these the symbols t_1, t_2, &c. are used. When all these corrections are applied, the tabular distances of limbs ought to $= 0$. This is the requirement which defines the form to be used for the equations; it is assumed that the probable error in satisfying this requirement is the same for each equation.

The equation was formed for every recorded observation. I do not here give all the details; I may, however, state that the number of observations was 54, made by 18 observers; and the number of equations was therefore 54.

The following are the sums of the equations at each station. It is to be remarked that δ.RA, δ.NPD, and $\rho - \beta$, are expressed in seconds of arc; that t_1, t_2, &c. are expressed in seconds of time; and that the other coefficients are abstract numbers.

Ingress at Honolulu, 10 observations:

$$+ 7^{s}{\cdot}40 = -2''{\cdot}280 \times n + 6{\cdot}5324 \times \delta.\mathrm{RA} - 7{\cdot}0606 \times \delta.\mathrm{NPD} - 10 \times (\rho - \beta) - 0''{\cdot}342 \times t_1.$$

Ingress at Rodriguez, 8 observations:

$$+ 54''{\cdot}14 = +1''{\cdot}554 \times n + 4{\cdot}8868 \times \delta.\mathrm{RA} - 5{\cdot}9946 \times \delta.\mathrm{NPD} - 8 \times (\rho - \beta) - 0''{\cdot}247 \times t_2.$$

Ingress at Kerguelen, 9 observations:

$$+ 61''{\cdot}03 = +1''{\cdot}937 \times n + 5{\cdot}3908 \times \delta.\mathrm{RA} - 6{\cdot}8446 \times \delta.\mathrm{NPD} - 9 \times (\rho - \beta) - 0''{\cdot}267 \times t_3.$$

Ingress at New Zealand, 2 observations:

$$+ 14''{\cdot}20 = +0''{\cdot}028 \times n + 1{\cdot}2347 \times \delta.\mathrm{RA} - 1{\cdot}4861 \times \delta.\mathrm{NPD} - 2 \times (\rho - \beta) - 0''{\cdot}064 \times t_4.$$

Egress at Mokattam and Suez, 7 observations:

$$+ 26''{\cdot}01 = -1''{\cdot}415 \times n - 1{\cdot}7146 \times \delta.\mathrm{RA} - 6{\cdot}7488 \times \delta.\mathrm{NPD} - 7 \times (\rho - \zeta) + 0''{\cdot}239 \times t_5.$$

Egress at Luxor, 5 observations:

$$+19''\cdot17 = -0''\cdot954\times n - 1\cdot2022\times\delta.\mathrm{RA} - 4\cdot8272\times\delta.\mathrm{NPD} - 5\times(\rho-\zeta) + 0''\cdot169\times t_6.$$

Egress at Rodriguez, 9 observations:

$$+34''\cdot73 = -0''\cdot245\times n - 1\cdot9692\times\delta.\mathrm{RA} - 8\cdot7432\times\delta.\mathrm{NPD} - 9\times(\rho-\zeta) + 0''\cdot294\times t_7.$$

Egress at Kerguelen, 4 observations:

$$+14''\cdot09 = +0''\cdot403\times n - 0\cdot7834\times\delta.\mathrm{RA} - 3\cdot9091\times\delta.\mathrm{NPD} - 4\times(\rho-\zeta) + 0''\cdot125\times t_8.$$

It was then necessary to consider the details in the mode of combining these equations, and the subjects to which the solution should be directed.

The equations are favourable for the determination of n, of $\delta.\mathrm{RA}$, and of $\delta.\mathrm{NPD}$. But when we examine the position of $\rho-\beta$ and $\rho-\zeta$, a new consideration presents itself. The quantity ρ as a matter affecting observation is not independent of $\delta.\mathrm{RA}$ and $\delta.\mathrm{NPD}$. We can, by alteration of $\delta.\mathrm{RA}$ and $\delta.\mathrm{NPD}$, alter ρ by any amount, and by the same amount at Ingress and at Egress. I have thought it best, therefore, to place ρ, as an undetermined constant, on the constant side of the equation, and, carrying its factor through all the operations which lead to ultimate solution, to exhibit its effect on the final results for n, for $\delta.\mathrm{RA}$, and for $\delta.\mathrm{NPD}$. And I have treated the effects of possible errors of Greenwich time on each sum of equations (t_1, t_2, &c. multiplied by the number of equations) in the same way.

For correct application of the Theory of Probabilities, it is necessary to give such a form to each of the equations which are to be collected that the probable errors of all will be equal. Let e be the probable error of the equation given by one observation (all being supposed liable to the same chance-error, as has been mentioned). Then the probable error of the sum of the ten equations at Honolulu will be $e\sqrt{10}$; the sum of the ten equations must therefore be divided by $\sqrt{10}$, and thus an equation is formed whose probable error is e. Now to form the Normal Equation most favourable for the determination of n (for instance), this equation of Honolulu (already formed by dividing the sum of equations by $\sqrt{10}$) must be multiplied by its coefficient of n (which has been formed by dividing the coefficient of n, in the sum of equations, by $\sqrt{10}$). And therefore, if the sum of equations for Honolulu be multiplied by its coefficient of n, the product must be divided by 10 in order to form the equation proper to enter into the combination which forms the Normal Equation. The same applies to $\delta.\mathrm{RA}$, $\delta.\mathrm{NPD}$. The general error of time t_1 will be simply multiplied by the reduced coefficient of n.

Similar remarks apply to the other stations.

The Normal Equations finally formed are the following:—

$$(1) \quad -2{\cdot}4658 = \left\{ \begin{array}{l} +1{\cdot}7543 \times n + 1{\cdot}1881 \times \delta.\mathrm{RA} + 1{\cdot}0807 \times \delta.\mathrm{NPD} - 1{\cdot}2390 \times (\rho-\beta) + 2{\cdot}2110 \times (\rho-\zeta) \\ +{\cdot}0780 \times t_1 - {\cdot}0480 \times t_2 - {\cdot}0575 \times t_3 - {\cdot}0009 \times t_4 - {\cdot}0483 \times t_5 - {\cdot}0322 \times t_6 - {\cdot}0080 \times t_7 + {\cdot}0126 \times t_8 \end{array} \right\}$$

$$(2) \quad +108{\cdot}2705 = \left\{ \begin{array}{l} +1{\cdot}1881 \times n + 12{\cdot}5369 \times \delta.\mathrm{RA} - 7{\cdot}8001 \times \delta.\mathrm{NPD} - 18{\cdot}0450 \times (\rho-\beta) + 5{\cdot}6695 \times (\rho-\zeta) \\ -{\cdot}2234 \times t_1 - 1{\cdot}1509 \times t_2 - 1{\cdot}1599 \times t_3 - {\cdot}0395 \times t_4 - {\cdot}0585 \times t_5 - {\cdot}0406 \times t_6 - {\cdot}0643 \times t_7 - {\cdot}0245 \times t_8 \end{array} \right\}$$

$$(3) \quad -243{\cdot}9714 = \left\{ \begin{array}{l} +1{\cdot}0807 \times n - 7{\cdot}8001 \times \delta.\mathrm{RA} + 39{\cdot}2672 \times \delta.\mathrm{NPD} + 21{\cdot}3858 \times (\rho-\beta) + 24{\cdot}2283 \times (\rho-\zeta) \\ +{\cdot}2415 \times t_1 + {\cdot}1851 \times t_2 + {\cdot}2031 \times t_3 + {\cdot}0476 \times t_4 - {\cdot}2304 \times t_5 - {\cdot}1632 \times t_6 - {\cdot}2856 \times t_7 - {\cdot}1222 \times t_8 \end{array} \right\}.$$

And their solutions are:—

$$n = \left\{ \begin{array}{l} -2{\cdot}1911 + 0{\cdot}0429 \times (\rho-\beta) - 0{\cdot}1331 \times (\rho-\zeta) \\ -{\cdot}0606 \times t_1 + {\cdot}0249 \times t_2 + {\cdot}0310 \times t_3 - {\cdot}0011 \times t_4 + {\cdot}0185 \times t_5 + {\cdot}0118 \times t_6 - {\cdot}0100 \times t_7 - {\cdot}0143 \times t_8 \end{array} \right\}$$

$$\delta.\mathrm{RA} = \left\{ \begin{array}{l} +5''{\cdot}7227 - 1{\cdot}2502 \times (\rho-\beta) - 0{\cdot}9371 \times (\rho-\zeta) \\ +''{\cdot}0237 \times t_1 + ''{\cdot}0072 \times t_2 + ''{\cdot}0069 \times t_3 + ''{\cdot}0029 \times t_4 + ''{\cdot}0071 \times t_5 + ''{\cdot}0050 \times t_6 + ''{\cdot}0123 \times t_7 + ''{\cdot}0062 \times t_8 \end{array} \right\}$$

$$\delta.\mathrm{NPD} = \left\{ \begin{array}{l} -5''{\cdot}0164 - 0{\cdot}2977 \times (\rho-\beta) - 0{\cdot}7995 \times (\rho-\zeta) \\ +''{\cdot}0001 \times t_1 - ''{\cdot}0039 \times t_2 - ''{\cdot}0046 \times t_3 - ''{\cdot}0005 + t_4 + ''{\cdot}0069 \times t_5 + ''{\cdot}0051 \times t_6 + ''{\cdot}0101 \times t_7 + ''{\cdot}0046 \times t_8 \end{array} \right\}$$

where $\rho-\beta$ and $\rho-\zeta$ are expressed in seconds of arc, and t_1, t_2, &c. in seconds of time.

The value of Equatoreal Mean Solar Parallax, corresponding to $n = -2{\cdot}1911$, is $8''{\cdot}754$; and the mean distance of the Sun's centre is 93,375,000 miles.

In adopting for the results the form in which they are here exhibited, I have endeavoured to make them the most complete which it is possible to extract from the Telescopic Observations of the Transit of *Venus* now treated.

Royal Observatory, Greenwich, 1877, *November* 6.

Statement of Mr. Gill's Observations of Mars obtained at Ascension between July 31 and September 4, both inclusive.

	Date.	Evening Observations. Stars of Comparison observed.	Hour-angle of first and last Obs.	Temp. (F.) before and after Obs.	Barom. before and after Obs.	Morning Observations. Stars of Comparison observed.	Hour-angle of first and last Obs.	Temp. (F.) before and after Obs.	Barom. before and after Obs.	
	1877.		h m	°	in.		h m	°	in.	
	July 31	$q_2\ n_2\ t_2$	4 30	74·5	30·167	$q_2\ n_2\ t_2$	0 27	72 6	30·164	Made at Garrison.
Shifting from Garrison to Mars Bay.			2 32	73·5	30·150		2 40	72·8	30·116	
	Aug. 5	$q_2\ n_2\ t_2$	4 51	75·0	30·223	$q_1\ t_1\ n_2$	1 7	73·5	30·164	Made at Mars Bay
Ill in bed			3 21	74·0	30·223		2 51	74·2	30·183	
	Aug. 10	...	...	...	...	$q_1\ t_2\ n_2$	2 43	73·6	30·190	do.
							3 45	73·5	30·209	
	Aug. 12	$q_2\ n_2\ t_2$	4 35	73·0	30·201	...	...	...	...	do.
			3 21	72·7	30·195					
	Aug. 13	...	...	...	...	$q_1\ t_2\ n_2$	2 3	71 7	30·164	do.
							2 59	71·9	30·175	
	Aug. 14	$q_2\ n_2\ t_2$	5 18	73·0	30·188	$q_1\ t_1\ n_1$	1 59	72·5	30·162	do.
			3 23	72·7	30·199		3 11	72·1	30·176	

Date.	Evening Observations. Stars of comparison observed.	Hour-angle of first and last Obs.	Temp. (F.) before and after Obs.	Barom. before and after Obs.	Morning Observations. Stars of comparison observed.	Hour-angle of first and last Obs.	Temp. (F.) before and after Obs.	Barom. before and after Obs.	
1877.		h m	°	in.		h m	°	in.	
Aug. 15	$q_2\ s_2\ n_2$	4 2	73·8	30·177	$q_1\ s_1\ n_2$	1 55	72·2	30·157	Made at Mars Bay.
		2 58	73·0	30·150		3 29	73·0	30·130	
Aug. 16	$q_2\ s_2\ n_2$	4 17	73·5	30·173	$q_1\ s_1\ n_1$	3 34	73·2	30·134	do.
		2 50	73·3	30·179		4 2	72·3	30·146	
Aug. 19	$m_2\ n_2\ r_2$	4 34	73·5	30·183	$m_1\ n_1\ r_1$	2 49	73·3	30·143	do.
		3 27	73·1	30·209		3 29	73·1	30·193	
Aug. 20	$n_2\ r_2\ \lambda_2$	4 14	74·0	30·184	$n_1\ r_2\ \lambda_2$	1 51	72·3	30·180	do.
		3 11	73·3	30·192		3 31	72·8	30·138	
Aug. 21	...	...	...	...	$n_1\ r_2\ \lambda_2$	1 40	72·7	30·117	do.
						4 37	72·0	30·130	Much cloud; long delay.
Aug. 23	$n_1\ r_3\ l_3$	4 51	74·3	30·164	...	...	...	...	Made at Mars Bay.
		2 33	73·7	30·182					
Aug. 24	$n_2\ q_3\ l_2$	4 43	74·7	30·150	$q_3\ l_3\ n_2$	1 58	73·1	30·122	do.
		2 32	74·0	30·175		4 4	74·4	30·119	

Aug. 26	$n_2\, q_3\, l_2$	4 44	74·5	30·100	...	...	...	...	do.
		2 24	73·8	30·123					
Aug. 27	$n_2\, h_2\, l_2\, m_2\, \lambda_1$	4 56	73·9	30·113	...	...	...	...	do.
		2 15	73·5	30·137					
Aug. 29	$i_1\, m_3 f_1\, h_1\, \lambda_1$	4 35	73·5	30·150	$\lambda_1\, h_2\, m_3 f_1\, i_1$	1 37	72·1	30·096	do.
		2 53	73·0	30·150		3 31	72·9	30·082	
Aug. 31	$f_2\, m_2$	3 36	74·2	30·142	$f_2\, m_2$	1 30	72·9	30·100	do.
		2 29	73·7	30·153		3 0	73·0	30·100	The planet in the line joining the stars; third star not required.
Sept. 2	$g_3\, \lambda_3\, k_1\, i_1$	3 43	74·2	30·116	...	...	...	...	Made at Mars Bay.
		1 51	73·2	30·150					
Sept. 4	$f_2\, k_2\, g_4$	4 48	73·9	30·122	...	...	...	...	do.
		3 4	73·3	30·150					

The figures subfixed to the letters indicating the stars of comparison observed show how many *complete measures* of the distance of the planet from the star have been observed.

A *complete measure* means four bisections so arranged as to eliminate index error of the instrument and error in the assumed diameter of the planet.

Statement of Mr. Gill's Observations of Mars obtained at Ascension between September 5^{d}·0 and the end of the Series of Observations.

Date.	Evening Observations. Stars of comparison observed.	Hour-angle of first and last Obs.	Temp. (F.) before and after Obs.	Barom. before and after Obs.	Morning Observations. Stars of comparison observed.	Hour-angle of first and last Obs.	Temp. (F.) before and after Obs.	Barom. before and after Obs.	
1877.		h m	°	in.		h m	°	in.	
Sept. 5	$g_6\ f_1\ h_1$	4 39	74·2	30·169	g_{12}	0 37	72·7	30·168	
		2 58	73·5	30·189		4 15	71·9	30·128	
Sept. 6	$f_3\ g_4\ e_2\ h_1$	4 47	74·1	30·170	$g_2\ e_2\ h_1$	1 28	72·4	30·164	
		2 21	73·0	30·191		3 38	72·0	30·139	
Sept. 7	$g_1\ e_2\ h_1\ d_1\ f_1\ k_1\ \gamma_1$	4 37	74·3	30·166	$e_1\ g_2$	1 36	72·6	...	Much cloud & delay
		2 28	73·0	30·200		3 51	72·7		
Sept. 8	$g_2\ e_3\ h_2$	4 32	74·1	30·174	$d_1\ k_1\ \gamma_1\ f_1\ g_1\ e_2\ h_2$	1 3	72·5	30·195	
		2 38	73·4	30·195		4 20	72·6	30·164	
Sept. 9	$g_1\ e_1$	3 27	73·6	30·180	$d_1\ \theta_1\ g_4\ e_4$	1 36	73·0	30·154	
		3 4	73·7	30·196		4 31	72·7	30·142	
Sept. 10	$g_2\ e_2\ \theta_1\ d_1\ f_1\ \gamma_1$	3 37	74·0	30·162	$g_4\ e_4$	2 31	72·5	30·150	
		1 44	73·2	30·186		4 16	72·0	30·137	
Sept. 11	$g_3\ e_2\ \mu_2$	4 36	74·2	30·162					
		3 10	73·4	30·199					

Sept. 15	$c_1\ e_1$	3 32	73·0	30·132	...	...	...	...	The distance μ is very small. It is proposed to combine these, assuming a uniform scale value for both nights.
		3 9	not read						
Sept. 16	μ_2	4 0	72·5	30·088	...	...	...	...	
		3 40	not recorded						
Sept. 17	$c_2\ e_2\ \beta_2\ \mu_2$	4 22	72·3	30·064	$\beta_1\ e_1$	3 2	71·5	30·091	Long interruption by cloud.
		1 28	71·8	30·100		4 40	69·7	30·050	
Sept. 19	$e_2\ b_2\ c_1$	3 41	72·9	30·070	$e_2\ b_2\ c_1$	1 20	72·1	30·100	
		2 14	72·0	30·096		4 0	71·5	30·036	
Sept. 22	$\mu_1\ c_1$	1 47	...	...	c_1	1 45	72·3	30·092	
		1 27	73·3	30·100		1 59	73·0	30·080	Read after long delay.
Sept. 23	$\mu_2\ b_2\ c_1$	4 24	74·0	30·066					
		3 7	73·0	30·093					
Sept. 24	$a_1\ b_2\ c_1\ \beta_2$	4 9	73·3	30·055	$a_1\ b_1\ c_1\ \beta_2$	2 19	72·2	30·083	
		2 9	72·7	30·100		3 50	70·8	30·045	
Sept. 25	...	...	...	...	$a_1\ b_1\ c_1\ \beta_1$	2 44	73·0	30·084	
						4 35	72·3	30·058	
Sept. 27	$a_2\ b_1\ c_1\ \beta_1$	3 34	74·0	30·134					
		2 32	73·2	30·144					
Oct. 3	$a_2\ b_2$	3 44	...	...	$a_3\ b_3$	1 31	73·0	30·136	
		1 41	74·3	30·136		4 28	72·0	30·094	

On the Proper Motions of Groombridge 2275 and 2276 (Σ. 1972).

By E. Dunkin, Esq. F.R.S.

The components of this interesting pair of stars, first observed by W. Herschel on 1782, October 12, and afterwards by J. Herschel and South, and W. Struve, under the designation of π' *Ursæ Minoris*, are separated by more than 30″, and according to Struve they are of the sixth and seventh magnitude respectively. There has been some evidence to support the notion that they are physically associated, but little can be gathered in confirmation from the measures hitherto made; on the contrary, the great angular distance between them would rather lead one to suppose that they are seen only optically double. There are, however, several pairs, or groups, of stars forming stellar systems much more widely separated, including some of those recently pointed out by M. Flammarion. Mr. Carrington must have believed in the affinity of these stars, for in his Redhill Catalogue he has inserted a note opposite Groombridge 2276, stating that its place is affected by "proper motion and rotation," to account for an apparent discordance between his resulting R.A. and N.P.D. and that derived from the observations of Professor Schwerd, of Speyer, without, however, giving any authority for the remark. The exact value of the annual proper motions was probably not known to Mr. Carrington, though he had ample data at his command for a fair approximation. It is now found that they are of nearly equal amount—$-0^s.067$ and $-0^s.056$ respectively in R.A., and $-0''.13$ and $-0''.17$ in N.P.D.; but, considering that the stars are situated only about nine degrees from the Pole, these quantities are not very remarkable. They are, however, of sufficient magnitude to justify their record in the *Monthly Notices*.

I have lately had occasion to verify the mean R.A. and N.P.D. of these stars given in the Greenwich annual star Catalogue for 1875, January 1, by bringing up to the same epoch the R.A. and N.P.D. inserted in the Groombridge and Radcliffe Catalogues. In doing this, my attention was drawn to the large and nearly equal discordances between the computed and the Greenwich Catalogue places, caused evidently by the separate undetermined proper motions of the stars. The discordances both in R.A. and N.P.D. were considerable, amounting to several seconds in each.. Both stars were fortunately observed by Lalande on 1790, March 21, and the reduced mean places for January 1 of that year are contained in Fedorenko's Catalogue of his circumpolar stars. The long interval between 1790 and the dates of the modern observations is especially favourable for an accurate determination of the annual proper motion of each star in both elements. It has been considered sufficient for the purpose of our inquiry to confine the comparison of Lalande's places

with those in the Radcliffe, Redhill, and Greenwich (1875) Catalogues. A separate comparison between the Groombridge and Greenwich places has, however, also been made as a check on the accuracy of the adopted values.

Although it seems premature at present to say that this pair of stars belongs to one stellar system, for the evidence is still insufficient, yet their resulting values of proper motion show conclusively that the two stars are travelling in space in the same direction with an almost equal velocity. The small change in their angular position and distances since the first observations of W. Herschel proves that they are too far separated to have much apparent gravitational effect on each other's movements, but, on the other hand, they appear to be sufficiently near to be mutually influenced by one common law of motion. The discordances between the different early measures of angular distance are greater than one would have expected, or we might probably have been able to give a more definite opinion. More light would, however, be thrown on the separate movements of these two stars if an accurate series of micrometrical measures of their angular position and distance were made at the present time to compare with the former measures. A few more meridional observations of the R.A. and N.P.D. of both stars are also desirable.

The following tabular statement contains the excess of the mean R.A. and N.P.D.—derived from Fedorenko's Lalande by the application of the geometrical precession—over the respective R.A. and N.P.D. printed in the Radcliffe and Redhill Catalogues, and in the annual star catalogue in the *Greenwich Observations* for 1875 :—

Catalogue.	Interval between Mean Epochs of Observation.	Excess of R.A. in Catalogues over R.A. from Lalande.		Annual Proper Motion in R.A.	
	Years.	G. 2275. s	G. 2276. s	G. 2275. s	G. 2276. s
Radcliffe	60·0	−3·87	−3·29	−0·0645	−0·0548
Redhill	66·2	−4·35	−3·72	−0·0657	−0·0562
Greenwich	85·2	−6·00	−4·73	−0·0704	−0·0555

Catalogue.	Interval between Mean Epochs of Observation.	Excess of N.P.D. in Catalogues over N.P.D. from Lalande.		Annual Proper Motion in N.P.D.	
	Years.	G. 2275. "	G. 2276. "	G. 2275. "	G. 2276. "
Radcliffe	55·5	−6·33	− 8·41	−0·114	−0·152
Redhill	66·2	−9·69	−13·11	−0·146	−0·198
Greenwich	85·2	−9·95	−13·26	−0·117	−0·156

The means of the annual proper motions resulting from the three comparisons are as follow :—

	Annual Proper Motion In R.A. s	In N.P.D. "
Groombridge 2275	−0·0669	−0·126
,, 2276	−0·0555	−0·169

These values have been used whenever required; but, as a check on the accuracy of Lalande's places, I have thought it desirable to make an additional comparison by substituting the Groombridge Catalogue for Fedorenko's Lalande. The Groombridge N.P.D. of 2276 is apparently more than four seconds in error, as may be observed below; the proper motion in N.P.D. of this star deduced from this second comparison is therefore too small. The remaining values are almost identical with those determined from the comparison with Lalande. The following are the resulting annual proper motions, using the Groombridge and Greenwich (1875) places only:—

	P.M. in R.A. s	P.M. in N.P.D. ″
Groombridge 2275	−0·064	−0·12
„ 2276	−0·055	−0·10

The following differences between the R.A. and N.P.D. of the two stars are taken from the mean places given in the respective catalogues:—

Catalogue.		Δ R.A. s	Δ N.P.D. ″
Fedorenko's Lalande	(1790)	12·50	0·0
Groombridge	(1810)	12·66	−5·1
Schwerd	(1828)	12·80	−0·4
Struve	(1830)	12·70	−0·8
Radcliffe	(1845)	12·80	−2·9
Redhill	(1855)	12·80	−4·4
Greenwich	(1875)	12·85	−4·6

Kidbrooke, Blackheath,
1877, *October* 22.

Note on the supposed Physical Association of Groombridge 3477 *and* 3511. By E. Dunkin, Esq. F.R.S.

In M. Flammarion's paper, "Sur un système stellaire en movement propre rapide" (*Comptes Rendus*, No. 8, August 20, 1877), he has exhibited what seems to be a remarkable instance of two stars, separated by more than six minutes of right ascension and nearly ten minutes of polar distance, travelling apparently together in space in the same direction with almost equal proper motions. Assuming that the proper motions employed by him are correct, he concludes that the association of these stars, one of which is a close double, forms a *stellar system* resembling in a great measure the stars 36 *Ophiuchi* and 30 *Scorpii*, which are separated as much as 12′ 21″ in a great circle, but have a common proper motion of some magnitude.

Perhaps I may be permitted to remark that a few years ago the large proper motion in R.A. of one of the stars in question, Groombridge 3511, inserted in the British Association Catalogue, appeared to me to be much too great, and consequently a new value was determined by comparing the Groombridge place with that observed in recent years at Greenwich. This new value has been referred to in a footnote on page 16 of the annual star Catalogue in the volume of *Greenwich Observations* for 1871 as follows:—"The proper motion, $+0^{s}\cdot049$, adopted for this star is determined from a comparison of the R.A. in Groombridge's Catalogue with the R.A. from Greenwich observations made between 1871, October 17, and 1873, March 27. The value, $+0^{s}\cdot119$, inserted in the British Association Catalogue, appears to be erroneous." A more recent comparison of the Groombridge and Radcliffe places with the observations made at Greenwich from 1871 to 1875 gives respectively for the annual proper motion in R.A. $+0^{s}\cdot048$ and $+0^{s}\cdot053$. To these I add another determination from recent Greenwich observations only, from four made in 1860 and 1861, and seven made since the beginning of 1871. The result is remarkably accordant with the others, though the interval is only twelve years.

	Annual Proper Motion in R.A. s	Annual Proper Motion in N.P.D. ″
Groombridge with Greenwich (1872)	+0·048	−0·01
Radcliffe „ „	+0·053	+0·07
Greenwich (1860–61) „	+0·049	+0·05

The means of these values are respectively $+0^{s}\cdot050$ in R.A. and $+0''\cdot043$ in N.P.D.

The evidently erroneous values, $+0^{s}\cdot119$ and $-0''\cdot10$, given in the British Association Catalogue having been employed by M. Flammarion in his investigation, his conclusions respecting the probable physical association of these two Groombridge stars will require some reconsideration.

Kidbrooke, Blackheath,
1877, *October* 30.

Note upon the Proper Motion of Groombridge 3511.

By Prof. T. H. Safford.

The supposed proper motion of the star Groombridge 3511

$+0^{s}\cdot119$ and $+0''\cdot10$

in Right Ascension and Declination respectively, as given in the British Association Catalogue, is derived from the comparison of

Pond's position for 1830 with that of Groombridge 1810. It is, however, too large, and the component in Declination has the wrong sign, as will appear from the following tabulation of the positions for 1855, as brought up in Argelander's manner, by the application, namely, of the systematic corrections given in volume vii. (Introduction) of the Bonn observations, and of precession, secular variation, and the third term of the series as computed by means of Bessel's constants of precession, and an approximate position for 1855.

The precession formulæ from 1855 to $1855+t$ are for this star,

$$\alpha'-\alpha = -1^s\cdot52163\,t-0^s\cdot2656\,\frac{t^2}{200}-0^s\cdot537\left(\frac{t}{100}\right)^3,$$

$$\delta'-\delta = +15''\cdot8540\,t-0''\cdot1435\,\frac{t^2}{200}-0''\cdot427\left(\frac{t}{100}\right)^3.$$

In the following table the later observations receive only approximate systematic corrections, and in Declination zero; as Argelander found large discrepancies near the Pole, owing to the few stars of the *Tabulæ Reductionum* in that region. The observations denoted by H. C. were made at Cambridge, partly by myself, and reduced by the help of the *Berliner Jahrbuch*.

I have here at my command an old transit instrument by Simms, and will observe the star again so soon as the instrument shall be repaired. The error in the B.A.C. proper motion, like that of many other stars, was noted by me long ago; and I have in hand a series of several hundred stars the proper motion whereof has been incompletely discussed elsewhere, of which this is one.

The columns C−O contain the differences in hundredths of seconds of time and in seconds of space respectively from the formulæ

$$\alpha = 21^h\ 28^m\ 57^s\cdot09+0^s\cdot016\ (t-1855),$$
$$\delta = 79^\circ\ 53'\ 29''\cdot2\ -0''\cdot018\ (t-1855).$$

The resulting annual proper motion, $+0^s\cdot016$ (in R.A.) and $-0''\cdot018$ in Declination, is still a little uncertain in amount.

The collection of observations may be very easily incomplete, as I have not at hand all the Catalogues which probably contain the star.

Williams College, Williamstown, Mass., U.S.A.,
September 21, 1877.

Catalogue.	Epoch. Obs.	Epoch. Pos.	R.A. at Epoch. h m s	Corr. s	Decl. at Epoch. ° ′ ″	Corr. ″	Position, 1855. h m s	Position, 1855. ° ′ ″	No. of Obs.	C−O R.A.	C−O Decl.
F	1790·1	1790	21 30 30·67	+0·026	79 36 17·78	+0·17	21 28 57·25	79 53 31·2	4	−120	−0·8
L.L.	1790·4	1800	30 15·35	+0·768	38 59·95	+0·50	56·36	33·5	2	− 31	−3·1
Gr.	1809·7	1810	30 0·18	+0·726	41 32·4	+1·31	55·07	28·6	6	+130	+1·4
Pd.	1830·9	1830	...	...	46 51·77	+0·49	...	29·1	8	...	+0·5
	1831·7	1831	29 32·07	−0·037	47 8·55	+0·49	56·27	29·9	24	+ 45	−0·3
	1832·8	1832	29 31·01	−0·037	...	...	56·67	...	5	+ 6	...
Pulk.	1842·2	1845	29 12·13	+0·038	...	...	57·08	...	2	− 19	...
R.C.	1850·7	1845	...	...	50 49·6	+1·26	...	29·5	7	...	−0·2
	1851·8	1845	29 12·11	+0·014	...	...	57·04	...	4	...	...
$R.C._2$	1855·7	1860	...	...	54 49·1	+1·26	...	31·1	6	...	−1·9
	1857·1	1860	28 49·67	+0·03	...	...	57·34	...	3	− 22	...
Arg.	1860·6	1860	28 49·27	+0·001	54 47·54	0·0	56·91	28·3	2	+ 27	+0·8
	1861·8	1864	28 43·09	+0·011	55 51·64	0·0	56·89	29·0	2	+ 31	0·0
H.C.	1865·7	1865	28 42·163	0·000	...	...	57·51	...	10	− 25	...
Arg.	1873·4	1873	28 29·51	+0·011	58 13·47	0·0	57·34	28·3	3	+ 4	+0·6
Main	1874·7	1874	28 28·17	+0·055	58 29·92	0·0	57·62	29·0	13	− 21	−0·2

Additional Note concerning 3511 *Groombridge.*

Since writing my former Note upon this star's proper motion, I have received, by Professor Holden's kindness, the extracts from Struve's observations (1814–15) and Schwerd's Catalogue (Oeltzen) which relate to it. The following are the results :—

Catalogue.	Epoch. Obs.	Epoch. Pos.	R.A. at Epoch. h m s	Corr. s	Decl. at Epoch. ° ′ ″	Corr. ″	Position, 1855. h m s	Position, 1855. ° ′ ″	No. of Obs.	C−O R.A.	C−O Decl.
Str.	1814·7	1815	21 29 54·98	+0·209	...	...	21 28 56·38	...	7	+7	...
Schw.	1828·	1828	29 36·683	+0·043	79 46 20·6	0·0	56·60	79 53 29·2	3	+6	+0·5

It will be seen that Struve and Schwerd agree very nearly with the formula deduced in the previous Note; the discrepancies in Right Ascension, $+0^{s}\cdot07$ and $+0^{s}\cdot06$ respectively, are both less than $0''\cdot2$ of space, so that I have thought it unnecessary to make a new least-square solution.

Williamstown, Mass.,
September 26, 1877.

Note on the Second Catalogue of Micrometrical Measurements of Double Stars made at the Temple Observatory, Rugby.

By J. M. Wilson and G. M. Seabroke.

In the forthcoming volume of the *Memoirs* (vol. xliii.) will appear the Second Catalogue of our Micrometrical Measurements of 398 Double Stars. By some accident the introductory observations that were sent with them were mislaid, and the fact was not discovered till the sheets were printed off. We should be glad of an opportunity of making a few remarks on them.

They consist chiefly of measures made in the years 1874, 5, 6, 7, with a few of older date, and include the last measures taken in the old Observatory. The temporary building was taken down in June last, and a new and permanent Observatory has been built, along with a curator's house, on a site purchased for this purpose by the governing body. An honorary curator and sub-curator of the Observatory have been added to the staff of the school.

The instrument and the micrometer are the same as those described in the introduction to the First Catalogue (*Memoirs*, vol. xlii), viz. Alvan Clark's $8\frac{1}{4}$-inch refractor, and Dollond's parallel wire micrometer. The observations were made, with few exceptions, by ourselves, with the frequent assistance of Mr. Percy Smith, F.C.S. (the present sub-curator), in measures of position, when any doubt or discrepancy showed itself. A magnifying power of about 400 was always used.

As in previous years, much of the very limited time at our disposal has been spent in miscellaneous observations on the Moon, planets, clusters, nebulæ, &c., and in interesting and instructing members of the school in astronomical matters.

It may be of interest to give the result of an analysis of our distance-measures and those of Dunèr and Mr. Gledhill, made by Otto Struve in the *Vierteljahrschrift der Astronomischen Gesellschaft* (12. Jahrgang, 2 Heft.). He finds

Gledhill	= Dunèr + 0″·151	from 108	comparisons.
Wils. & Seab.	= Dunèr + 0″·143	„ 101	„
Struve	= Dunèr + 0″·101	„ 324	„

But he points out that Struve's distances need a constant correction of +0″·06. Hence, to reduce the distance-measures by these observers to a uniform scale, the following corrections must be applied:—

Struve	+0″·06	
Dunèr	+0″·17	for stars below 12″.
Gledhill	−0″·02	
Wils. & Seab.	−0″·03	

Otto Struve recommends us to separate our observations, so that it might be possible to ascertain our separate personal errors. We have, however, ascertained its amount from a considerable number of observations, viz. $W = S + 0''.1$, and this agrees very nearly with the amount ascertained by himself from the few separate observations published, viz. $W = S + 0''.15$. But, from a comparison of our own measures with those of others, we concluded that our errors were of opposite signs, and that the mean of our measures would not show any appreciable systematic error. This appears from Otto Struve's investigation to be the case. And on this ground we shall probably continue to give joint results, as being more trustworthy and more immediately available to the orbit computer.

We may add, moreover, that it is our opinion that a personal error in measures of this kind is very different in nature from those made in time observations; that it is masked in individual cases by accidental errors of far larger magnitude; and that it would be quite unsafe to apply it as a constant correction. Our present opinion is that a series of most careful measures of distance made by us on an easy star on a single fine night cannot be relied on to $0''.1$, and that the only way of getting greater accuracy is to multiply the nights of observation.

Otto Struve also expresses the wish that our distances should be given to hundredths of a second, and they are so given in the Second Catalogue. We are very grateful to him for his encouraging criticism, and his appreciation of our circumstances—"das Instrument in Rugby in grossem Maasse zur Befriedigung wissenschaftlicher Neugier dienen muss, und überdies die Beobachter durch ihre amtlichen Pflichten an der bekannten Lehranstalt vielfach in Anspruch genommen sind."

Rugby, Nov. 7, 1877.

On the Atmospheric Lines between the two D Lines.

By H. C. Russell, Esq., Director of the Sydney Observatory.

I have a powerful spectroscope made by Hilger, of London, of which the greatest dispersion is equal to eighteen 64° prisms, and the definition so fine that I can measure one three-hundredth part of the space between the D lines. With this I have frequently examined the lines between the D lines, and find only seven; while it is stated that at Potsdam nine are seen; and many years since (1868) Dr. Huggins saw twelve at Kew, and in 1875 Colonel Campbell recorded nineteen in London. These facts led me to make a careful examination and measures of all the lines I could see here. Perhaps the information may be interesting to the members of the Royal Astronomical Society.

The diagram has been prepared by enlarging the drawings kindly given to me by Dr. Huggins and Colonel Campbell, and a careful plot from my own measures. I may state that, in order

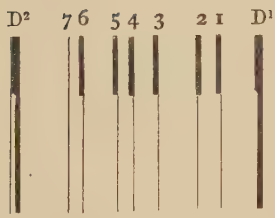
to identify the lines, I have numbered them 1 to 7, beginning at D1, and their positions, as determined by a number of readings with the micrometer, are as follows:—

D1	1	2	3	4	5	6	7	D2	D3
000	41	67	124	151	173	213	232	291	299

4 is the nickel line always seen; 7 is the position, or very near it, of the zinc line; 1, 2, 3, 5, and 6 are evidently atmospheric lines, as they always increased in distinctness very fast as the Sun neared the horizon; 4 also seems to enlarge as if there were an atmospheric line coincident with it, and 6 increased faster than any other; when the Sun was near the horizon it was as thick again as D1; 7 did not increase at all, and almost disappeared when the Sun was near setting.

Lines between the "D Lines."

Colonel Campbell, 1875, London; with spectroscope by Hilger (eight glass prisms); "enlarged."



Sydney Observatory, 1877; spectroscope by Hilger (glass prisms). As thickened at the top, the lines show the appearance at sunset.

Dr. Huggins, 1863, with Mr. Gassiott's spectroscope at Kew, since presented to Oxford (bisulphide of carbon prisms); enlarged.

I have no drawing of the lines seen at Berlin.

The line D_3 has not, I think, been described before. It is a difficult line to see, and only to be made out with high powers. I have not reduced my measure to wave lengths, because the results obtained by Dr. Huggins and Colonel Campbell are only recorded in drawings, without measures. I have had prepared enlarged drawings of those obtained at Kew and London, with a careful plot from my own measures, which I enclose.

There are not many of the lines which agree; but as Dr. Huggins used bisulphide of carbon prisms, and Colonel Campbell only eight prisms, some of the differences might disappear if all could be reduced to wave lengths. On closely comparing the drawings, it will be seen that five lines were recorded in London between my No. 7 and D_2, two others between D_1 and No. 1, and three between Nos. 2 and 3. These spaces appear in Sydney, even under the most favourable conditions, entirely free from lines, or any sign of them. It would appear, therefore, that there must be some gases in the atmosphere of Europe, and especially of London, which are not present in Australia, or at least at Sydney.

Sydney Observatory,
July 26, 1877.

On the Spectrum of a Solar Spot observed at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

A fine spot has recently passed across the Sun's disk, showing a spectrum remarkable for the number of lines which are more or less affected by increased absorption, as will be seen from the following table:—

Element.	Number of lines observed.	Character of Change.
Calcium	12	Very much darker, and about doubled in breadth.
Sodium	2	Very much darker. The two D lines almost meet over the nucleus.
Titanium	11	Very much darker, and about doubled in breadth.
Iron	30	Slightly broader, by about a tenth, and decidedly darker, about half as dark again.
Barium	4	About twice as dark and twice as broad.
Magnesium	4	Much broader and darker.
Nickel	6	Half as broad again. Slightly darker.
Chromium	3	Somewhat darker, and broader by about one-tenth.
Hydrogen	3	Much fainter and less distinct. F line reversed in the neighbourhood of the spot, due north of the centre, on Nov. 5.
Coronal line	1	Much fainter over the spot.
D_3	1	Not seen either bright or dark, in spot or bridge.
Telluric bands	1	Band α. Broader and darker.

The following lines and bands were also broadened:—

Line.	Wave length.	Character of Change.
K 588	6927	Darkened.
B	6869	Darkened and slightly broadened on the red side by about one tenth-metre of wave length.
K 712	6517	Double usual breadth. This is probably one of the lines of Barium.
K 765 ±	6380 ±	An appearance as of a dark shaded band, sharp towards the blue, and shaded off towards the red. Nothing seen on the Sun to correspond with it.
K 1493	5297	A cluster of several lines, of which only those on the blue side are affected. Much darker, and wider on the blue side by 0·3 tenth-metre of wave length. Two of these probably belong to Titanium.

Lines from Kirchhoff's map are denoted by the letter K and the No. on his scale.

Besides the increase in the breadth, displacements to the red or blue were noted, especially in the case of the F and D lines. On October 31 the F line was twisted, the part over the following half of the spot being displaced to the red, and the other half towards the blue, by amounts corresponding respectively to a recession or downward motion of nine miles, and an approach or upward motion of three miles a second. On the darkest part of the spot the D lines were broadened on the red side to the extent of $\frac{1}{2}(D_1 - D_2)$, the more refrangible edge being sharp, and not sensibly displaced. This would indicate a large downward motion of perhaps thirty miles a second. On other parts of the spot the haze appeared to be chiefly on the blue side. The spot was first seen (after an interval of cloudy weather) on October 30, when it was well advanced on the disk, and photographs were obtained on October 30, 31, November 1, 2, 3, 4, 5, during which period it underwent but little change, except that a group of small spots closely following it had closed up by November 5, leaving merely a group of faculæ, which were seen near the limb on November 8. The large spot would appear to have passed off about November $7^d\ 6^h$, but clouds prevented any observations between November 5 and 8. On November 8 there was no unusual disturbance of the chromosphere, the only indication of the position of the spot being a small jet 20″ high. With the exception of the group of faculæ the Sun appeared to be in a quiescent state.

The observations were made by Mr. Christie and Mr. Maunder, using the new "half-prism" spectroscope (direct-vision) with a train of two "half-prisms" reversed, so as to give great purity of spectrum.

Royal Observatory, Greenwich,
1877, *November* 9.

Note on the Spectrum of the Eclipsed Moon. By Capt. W. Noble.

Those Fellows of the Society who were present on March 9 will remember that, at the conclusion of Mr. Penrose's Paper on the "Total Lunar Eclipse of February 27," I made some oral remarks on the spectrum of the obscured Moon as viewed from my own station. Notwithstanding the vivid redness of the lunar disk as seen by the naked eye, I found, to my exceeding surprise, that its spectrum was cut off in a most remarkable manner at the least refrangible end; in fact, that, with a pretty wide slit, it did not begin very much before D, as determined by an extemporised sodium-spectrum. I learned afterwards that no such truncation was visible at Greenwich. Observing the second eclipse of the Moon this year (that of August 23) I once more turned my spectroscope on to the shadowed disk, this time to be struck by the brilliancy of the red end of the spectrum, which seemed to me to extend to little *a*, if not further. Now, however, comes the curious part of the story. In the supplementary number of the *Monthly Notices* I find that Mr. Christie and Mr. Maunder, observing at Greenwich, noticed that "the red and blue ends of the spectrum were completely cut off, whilst the orange was greatly reduced in intensity." This would surely seem to point to our own atmosphere as the immediate cause of this remarkable absorption. Forest Lodge is only some thirty-seven or thirty-eight miles, as the crow flies, from the Royal Observatory, but this is an interval which would admit of very diverse atmospheric conditions obtaining at the two stations. It may be that the recent curious and interesting discovery of what he calls the "rainband" by the Astronomer Royal for Scotland (of which his own account will be found in recent Nos. of the *Astronomical Register*) will afford at least a partial explanation of the remarkable discrepancy. I find, on reference to my own meteorological register, that rain fell at my station on February 27, when the red end of the spectrum was cut off, and that none descended there on August 23, when the spectrum extended so much further. At all events, there seems no escape from the conclusion that the cause of the variation was terrestrial. Had it had its origin outside of our atmosphere, that is in the quality of the light refracted within the Earth's shadow, no difference could possibly have been perceptible at places only thirty-seven miles apart.

Physical Observations of Mars, made at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

The spectrum of *Mars* has been examined on several occasions lately with the single-prism spectroscope, in order to detect either

traces of atmospheric absorption, or any differences in the spectrum as obtained from different parts of the disk. For the former purpose the spectrum of *Mars* was compared with that of the Moon on August 23 and September 26, when their altitudes were very nearly equal, that of *Mars* being 26° and 24° on the two occasions respectively, and of the Moon 24° and 23°. Several faint diffused bands, besides the sharp Fraunhofer lines, were observed in the spectrum of *Mars* on both occasions; and some of these were also seen on September 21, when the planet was again examined, but not compared with the Moon. The following table shows the wave-lengths of these bands, expressed in tenth-metres:—

Absorption Bands in Spectrum of Mars.

Line.		Aug. 23.	Sept. 21.	Sept. 26
Band δ of the Brewster spectrum	First edge	...	5640	5639
	Second edge	...	5661	5717
Group of lines round D	First edge	...	5889	5887
	Second edge	...	5907	5897
Faint band. Centre reading		6019	6022	...
Band α. Centre reading		6287	6287	6298
Very faint band. Centre reading		...	...	6511
Group of lines round C	First edge	6544	6537	6544
	Second edge	6572	6587	6575
Very faint band. Centre reading		...	...	6695
Very faint band B (?). Centre reading		6852	...	6895

Of these bands only the three most pronounced—viz. band α and the groups round C and D—were visible in the spectrum of the Moon. Of these α was only suspected to be present; the D group was decidedly narrower than in *Mars*, and that round C was only $\frac{2}{3}$ the breadth of the same group in *Mars*, and so much fainter that it was not seen until the pointer had been set to the proper reading for it, although, when once it had been found, it was easily recognised. The dispersive power of the spectroscope employed being small, and the red end of the spectrum much contracted, the groups of atmospheric lines round C and D would necessarily appear as an unbroken band.

On September 12, when the large dark spot, called in Proctor's Chart "Dawes Ocean," occupied the centre of the disk, the spectrum of *Mars* was examined for the detection of local differences. The dark spot gave a much fainter spectrum than the rest of the disk, the contrast being very marked in the red and yellow, and less so in the violet; it showed, however, no lines or bands other than those seen in other parts. The spectrum of the polar spot and its neighbourhood was very bright from about D to F, but showed very little red; the north limb, on the

contrary, gave a spectrum somewhat less bright in the green and yellow, but extending further into the red. The group round C seemed to be darker over "Dawes Continent" (the bright spot north of "Dawes Ocean") and less dark on the north limb. Bands a and B were seen, but no difference was remarked in their appearance from whatever part of the disk obtained; but, being fainter than C, a slight difference was less likely to be detected.

On September 21 and 26 the absorption bands then measured were noticed to be very slightly fainter on the limb than anywhere else. The locality where they were most distinct was variously estimated as from 5″ to 6″ from the limb on September 21, and from 3″ to 4″ on September 26. As the definition was much better on the latter occasion, the smaller estimation is more likely to be correct. The difference in intensity, except just on the limb, was exceedingly slight, but the point where the bands were estimated to be darkest was always found to be at very nearly the same distance from the limb.

The red end of the spectrum of *Mars* was much fainter on or near the limb, but the violet seemed of the same intensity from all parts of the disk, and was visible about as far as in the spectrum of the Moon.

The observations were made by Mr. Maunder.

Drawings (29 in all) have been made of the planet at every favourable opportunity during the late opposition, and some apparent changes, suggesting variations in the atmosphere of *Mars*, have been noted. It is, however, very difficult to determine how far such changes are due to the varying state of our own atmosphere. Variations were noted in the colour of the markings and in the comparative brightness of the limb, which usually presented the appearance of a bright ring, obliterating the dark markings more or less completely within about 4″ from the edge of the disk. The table shows the appearances that have been noted on various occasions, and the state of the definition corresponding.

Changes in Appearance of Mars.

1877.	Aug. 30.	Sept. 12.	Sept. 19.	Sept. 21.	Sept. 24 & 26.	Sept. 27 & 29.	Oct. 2.	Oct. 15.	Oct. 16.	Oct. 22.	Oct. 23.
Bright ring round limb.	Bright.	Bright.	Hardly visible; limb orange.	More apparent, but not so bright as on Sept. 12.	Not perceptible.	More marked.	Very marked.	Very marked.	Scarcely visible; dark markings visible up to limb.	Not marked.	Very bright on *p* side.
Dark spots.	Blue gray.	Dark olive green.	Neutral.	...	...	...	Neutral.	...	...	Dusky.	Cobalt blue.
Bright spots.	Rose.	...	Dull orange.	Yellower or whiter than on Sept. 19.	Orange; purer and livelier than on Sept. 19.	...	Livelier orange, brightening in parts into yellow or white.	...	...	Colour not marked.	Colour very marked; pale vermilion.
Definition.	...	Very good.	...	Trem. and bad.	Much better on Sept. 26.	Sept. 27, poor; Sept. 29, good.	Good, and very steady.	Bad, and unsteady.	Faint from fog, and not steady.	Good.	Very good.

The following points have also been noted:—On September 12 a thick cluster of points, darker than the bright spot but much brighter than the adjoining dark spot, formed a fringe on the border between Dawes Continent and Dawes Ocean (Proctor's Chart) or Hour-glass Sea, a boundary which, when seen under nearly the same aspect on September 7, had appeared remarkably sharp and distinct. On October 15 the long narrow bright strip stretching into the centre of the disk was very ill-defined at both ends, where it was both fainter and whiter than the rest. A very bright white spot was noted on October 22 on the *s.p.* limb in a position corresponding to the *p.* end of this strip. The large bright patch towards the *s.f.* limb (Lockyer Land of Proctor's Chart) seemed to move round a little more rapidly than the other markings, as if elevated above them. In the course of a couple of hours it seemed to have encroached on the dark strip on its *n.p.* side, making it appear narrower. The bright patch (Lockyer Land) was noted as being very bright and white on October 22. Dawes' so-called "Snow Island" was seen on October 2 as a white spot in De la Rue Ocean.

On August 30 the polar spot appeared to be serrated, showing three indentations round the edge when the definition was at its best. As far as could be judged, this was not an effect of tremor in the air. On September 29 the polar spot was noted as being irregular in shape, and on October 22 the dark ring round it appeared to be much darker on the *f.* side.

The above observations would appear to indicate the presence of occasional clouds in the atmosphere of *Mars*, but they require confirmation.

The outer satellite of *Mars* was seen on five nights and the inner on one, viz. September 28. Only one micrometer measure of the outer satellite was obtained, as follows:—

1877.	G.M.T. h m s	Pos. Angle. ° ′	Dist. (from 1st limb). ″
Sept. 29	8 54 56	248 31	67·5

Estimations were made on the other nights.

The observations were made by Mr. Christie and Mr. Maunder.

Royal Observatory, Greenwich,
1877, *November* 9.

Observations of Mars at Madeira, August and September 1877.

By N. E. Green, Esq.

Madeira was chosen as a place of observation for its southern position, its reputation for clear skies during the months of August and September, and because the heat at that season is less than at other places on the same parallel of latitude.

Observations were commenced on August 19 at a situation to the east of Funchal, having an elevation of 1,200 feet above the sea, and continued till September 14, when a move was made to a position a thousand feet higher, with the hope of improving the definition; but the change was not attended with any decisive advantage.

The great transparency of the atmosphere at Madeira encouraged the expectation of a corresponding degree of sharpness in the telescopic images; but its want of steadiness, arising apparently from conflicting currents of hot and cold air, seriously affected the performance of the instrument, and frequently restricted the amount of amplification that could be employed with advantage. Still there were many good evenings, and amongst them some which merited the term superb.

The following extract from the notes taken on the occasion will enable those interested in the matter to form their own estimate of the value of this situation for astronomical studies. There were altogether 47 nights during which the telescope was ready for work. Out of this number 26 were sufficiently favourable for the use of the pencil, leaving 21 on which no drawings could be made. Of the 26 possible occasions, 10 are entered as good, 4 as excellent, and 2 as grand and superb, the remaining 10 evenings being either passable or poor. They may be tabulated thus:—

Total number of nights	47
Number favourable for drawing	26
Wet, cloudy, or useless	21
	47
Of the 26 favourable nights—	
Entered as good	10
„ excellent	4
Grand and superb	2
Passable or poor	10
	26

Thus out of 47 nights there were 16 of good character, giving a proportion of one-third, a quantity considerably in excess of the average of an English climate. The instrument employed was a 13-inch silver-on-glass reflector, mounted as an altazimuth, its construction being of the most simple character, and so arranged that it could be readily taken to pieces and carried up the steep roads of the island. Its situation was changed four times, and each time it was removed and erected within the day, so that no night was lost.

The 13-inch mirror was figured by Mr. G. Wills, of Hereford, and most kindly lent by him for the occasion. Its performance either on planet or stars was simply perfect, the higher powers having apparently no effect on its definition. A very fine 12½-inch speculum by Messrs. Horne & Thornthwaite was also employed; and it may be worth the remark to those who are interested in these silver-on-glass mirrors, that the quality of their performance seemed to leave nothing to desire.

The method of mounting may be observed in the photographs which lie on the table. It will be seen that the framework which holds the mirrors in position is open to the external air, excepting at that portion which is nearest the observer; here it is partly closed in order to exclude any currents which might be formed by heat arising from the person. By this open arrangement the tube currents which so generally impair the performance of reflectors are impossible.

A Paper on this subject is in course of preparation, in which the results of the working of a 4-inch achromatic, a 9-inch reflector in the usual iron tube, and a 13-inch speculum mounted in an open frame are carefully registered, showing a most decided advantage in the open arrangement over the usual iron tube.

The drawings, 41 in number, were continued until the whole surface of the planet had passed before the eye, the same phase that had occupied the pencil at an advanced hour of the night on August 19 having returned to the meridian early in the evening of September 19. Drawings were continued till September 29, thus overlapping the series, and producing duplicates of many of the earlier views. Of these views twelve, which were produced on the most favourable occasions, have been carefully copied, and presented for the acceptance of the Society.

Each drawing was made direct from the telescope, and entirely independent of those which had been produced previously; all comparisons being reserved till the evening was over, so that each view might be as free as possible from bias, or a leaning towards the repetition of similar forms. Occasionally the planet was scrutinised most carefully, in order to verify, if possible, the drawings of others, and especially the maps published by Mr. Proctor from the drawings of Mr. Dawes. Attention was also given to the work of M. Terby, and an earnest effort made to answer each query of that painstaking astronomer.

The drawings furnish evidence of the general clearness of the atmosphere of *Mars*, the various details being fairly repeated from night to night, even after the retrograde movement due to the greater length of the Martial day had brought the same phase again to the meridian. The presence of an atmospheric envelope is, however, abundantly shown in the fading both of details and colour towards the limb, and especially from the singular absence of markings towards the north pole, where, in consequence of a lower temperature and shorter exposure to the Sun's rays, a greater amount of condensation would take place.

In connection with atmospheric effects, a most interesting observation was made on the evening of August 21. On this occasion a series of lines having a meridional direction were seen tending towards the north pole, possibly indicating the flow of currents of cold air to the equator; and on September 29 one of the most firm and definite lines on the planet, the eastern edge of the De la Rue Ocean, was in two places obscured by clouds.

The decrease of the polar zone of snow was most manifest, as in some drawings made in St. John's Wood previous to the voyage to Madeira this zone occupies a space fully twice as great as in those made towards the end of September. A most interesting observation was made on September 1. At 10.40 a brilliant spot of light was seen at a considerable distance from the edge of the snow, on the western portion of the ellipse; this was clearly seen again on the 2nd and 3rd of the month; and on the 8th, during which night the definition was superb, a second point was visible near the first; and again, on September 10, a series of fainter points were figured, forming a line concentric with the zone of snow. These isolated lights were doubtless due to the presence of high ground, which retained its covering of snow after it had disappeared from the lower surfaces. The outline of the zone was also broken up by dark valleys extending into it, and several irregular patches formed projections, which a further contraction might have left as outlying fields of snow.

It has been remarked that these snow caps do not agree exactly with the poles of the axis of revolution. It may be a confirmation of this statement to mention that by September 18, the zone, only a week after it had appeared so large and distinct, was considerably reduced in size and its outline very indefinite, whereas by the end of the month it had returned in great measure to its previous form and size; the rapidity and extent of this change being greater than could be attributed to simple alterations of temperature.

The portions of the planet's surface where the details observed seem least to agree with the drawings made during previous oppositions is that to the east of the De la Rue Ocean. Here are figured in Mr. Proctor's maps, and in the drawings of some eminent observers, two very similar forms called Lockyer Sea and Dawes Sea. Now the Lockyer Sea is perhaps the most definite separate dark spot on the planet. It was observed and figured at Madeira 18 times, but on no occasion could the Dawes Sea be made out. There is a very delicate shade proceeding from a more northern portion of the De la Rue Ocean, somewhat in the position where this sea is figured, and this may have been darker on previous oppositions, or the delicate shading of the original drawings may have been exaggerated either by engraver or printer.

The Lockyer Sea is generally represented as united to the De la Rue Ocean by a narrow inlet, and on one occasion it had

just this appearance at Madeira; but on the same evening, in steadier air and under a higher power, this appearance was found to be due to the presence of a small lake lying in the line of the supposed connection.

A most careful search was frequently made for the long snakelike form called Bessel Inlet; but, though the examination was continued on a favourable occasion for two hours, it was in vain.

The forms of the markings generally considered to exist both to the west and east of the Kaiser Sea are capable of improvement. They are very delicate, the finest air and considerable magnifying power being required for their observation.

The most earnest attention was given to the delineation of the south pole and its surroundings, in order to make the most of this memorable opposition, and there appears to be very strong evidence of the existence of a sea lying between the southern portion of Hook's Sea and that known as Phillips' Sea, which immediately surrounds the pole.

I cannot conclude this Paper without expressing my thanks to Mr. Marth, who has taken so great an interest in this effort, furnishing me, in the first place, with every information about the island, and afterwards sending me most valuable tables of the revolution of *Mars*, and the dates when certain markings would be on the meridian. I only regret that, in consequence of the close occupation of my time in making the drawings of *Mars*, and the weariness of body produced by work both by day and night, that I was not able to observe the satellites of *Saturn*, as that indefatigable computer would have desired. Still it is hoped that the Madeira observations will not be without result in advancing our knowledge of the most terrestrial of the heavenly bodies.

It is intended to add a critical examination of each of the drawings, together with several matters of interest connected with the observations; but these are more fitted to appear together with the publication of the views of the planet.

Sketches of Mars. By Capt. W. Noble.

The sketches of *Mars*, which I herewith present to the Society, almost explain themselves. They were all made with my (Ross) Equatoreal of 4·2 inches aperture and sixty-one inches focus, and with the same power of 255. I was never able to make out any markings on or near the northern limit of the planet; and, as a rule, all markings shaded off as they approached the preceding and following limbs. It will be noticed, however, that in the greater proportion of cases the markings are sharper and darker towards the following limb than towards the preced-

ing one, and in the not very frequent instances in which a dark marking is seen to extend actually *to* the limb itself, it is invariably the following one. This would seem to point to the fact that sunrise on *Mars* is much clearer than sunset; but I abstain from any theory as to the cause of this.

Forest Lodge, Maresfield, Uckfield,
November 8, 1877.

On the Motion of the Moon's Node in the case when the Orbits of the Sun and Moon are supposed to have no Eccentricities, and when their mutual Inclination is supposed to be indefinitely small. By Professor J. C. Adams, M.A.

A very able paper has recently been published by Mr. G. W. Hill, assistant in the office of the *American Nautical Almanac*, on the part of the motion of the lunar perigee which is a function of the mean motions of the Sun and Moon.

Assuming that the values of the Moon's coordinates in the case of no eccentricities are already known, the author finds the differential equations which determine the inequalities which involve the first power of the eccentricity of the Moon's orbit, and, by a most ingenious and skilful process, he makes the solution of those differential equations depend on the solution of a single linear differential equation of the second order, which is of a very simple form. This equation is equivalent to an infinite number of algebraical linear equations, and the author, by a most elegant method, shows how to develop the infinite determinant corresponding to these equations in a series of powers and products of the small quantities forming their coefficients. The value of the multiplier of each of such powers and products as are required is obtained in a finite form. By equating this determinant to zero, an equation is obtained which gives directly, and without the need of successive approximations, the motion of the Moon from the perigee during half of a synodic month. The small quantities which enter into the value of the above determinant are of the fourth, eighth, twelfth, &c. orders, considering, as usual, the ratio of the mean motion of the Sun to that of the Moon as a small quantity of the first order; and the author has taken into account all the terms of lower orders than the sixteenth. The ratio of the motion of the perigee to that of the Moon thus obtained is true to twelve or thirteen significant figures. The author compares his numerical result with that deduced from Delaunay's analytical formula, which gives the ratio just mentioned developed in a series of powers of m, the ratio of the mean motions of the Sun and Moon. The numerical

coefficients of the successive terms of this series increase so rapidly that the convergence of the series is slow, so that the terms calculated do not suffice to give the first four significant figures of the result correctly, although, by induction, a rough approximation may be made to the sum of the remaining terms of the series.

I have been led to dwell thus particularly on Mr. Hill's investigation because my own researches in the Lunar Theory have followed, in some respects, a parallel course, *sed longo intervallo.*

I have long been convinced that the most advantageous way of treating the Lunar Theory is, first, to determine with all desirable accuracy the inequalities which are independent of the eccentricities e and e', and the inclination $2\sin^{-1}\gamma$, and then, in succession, to find the inequalities which are of one dimension, two dimensions, and so on, with respect to those quantities.

Thus the coefficient of any inequality in the Moon's coordinates would be represented by a series arranged in powers and products of e, e', and γ, and each term in this series would involve a numerical coefficient which is a function of m alone and which may be calculated for any given value of m without the necessity of developing it in powers of m. The variations of these coefficients which would result from a very small change in m might be found either independently or by making the calculation for two values of m differing by a small quantity.

This method is particularly advantageous when we wish to compare our results with those of an analytical theory such as Delaunay's, in which the eccentricities and the inclination are left indeterminate, since each numerical coefficient so obtained could be compared separately with its analytical development in powers of m.

It is to be remarked that it is only the series proceeding by powers of m in Delaunay's Theory which have a slow rate of convergence, so that it is probable that all the sensible corrections required by Delaunay's coefficients would be found among the terms of low order in e, e', and γ.

The differential equations which would require solution in these successive operations after the determination of the inequalities independent of eccentricities and inclination would be all linear and of the same form.

It is many years since I obtained the values of these last-named inequalities to a great degree of approximation, the coefficients of the longitude expressed in circular measure, and those of the reciprocal of the radius vector, or of the logarithm of the radius vector, being found to ten or eleven places of decimals.

In the next place I proceeded to consider the inequalities of latitude, or rather the disturbed value of the Moon's coordinate perpendicular to the ecliptic, omitting the eccentricities as before, and taking account only of the first power of γ.

In this case the differential equation for finding z presents itself naturally in the form to which Mr. Hill reduces, with so much skill, the equations depending on the first power of the eccentricity of the Moon's orbit.

In solving this equation I fell upon the same infinite determinant as that considered by Mr. Hill, and I developed it in a similar manner in a series of powers and products of small quantities, the coefficient of each such term being given in a finite form.

The terms of the fourth order in the determinant were thus obtained by me on the 26th December 1868. I then laid aside the further investigation of this subject for a considerable time, but resumed it in 1874 and 1875, and on the 2nd of December in the latter year I carried the approximation to the value of the determinant as far as terms of the twelfth order, or to the same extent as that which has been attained by Mr. Hill. I have also succeeded in reducing the determination of the inequalities of longitude and radius vector which involve the first power of the lunar eccentricity to the solution of a differential equation of the second order, but my method is much less elegant than that of Mr. Hill.

Immediately after Mr. Hill's paper reached me, I wrote to him expressing my opinion of its merits, and telling him what I had done in the same direction, and I received from him a very cordial and friendly letter in reply.

The equation which I had obtained by equating the above-mentioned determinant to zero differed in form from Mr. Hill's, and on making the reductions required to make the two results immediately comparable, I found that there was an agreement between them except in one term of the twelfth order. On examining my work I found that this arose from a simple error of transcription in a portion of my work, and that when this had been rectified my result was in entire accordance with Mr. Hill's.

The calculations by which I have found the value of the determinant are very different in detail from those required by Mr. Hill's method, and appear to be considerably more laborious. I have not yet had time to copy out and arrange the details of the calculations from my old papers, but I hope soon to do so, thinking that they may not be without interest for the Society. Meantime I now make known the result which I have obtained for the motion of the Moon's node on the suppositions stated in the title of this paper.

If nt and $n't$ represent the mean longitudes of the Moon and the Sun at time t, omitting, for the sake of brevity in writing, the constants which always accompany nt and $n't$, and if θ and r represent the Moon's longitude and radius vector, I find that, in the case of no eccentricities and inclination, if $m = \frac{n'}{n} = 0{\cdot}0748013$, which is the value used by Plana,

$$\begin{aligned}\theta = nt &+ 0{\cdot}01021{,}13629{,}5 \sin\ 2\,(n-n')\,t\\ &+ 0{\cdot}00004{,}23732{,}7 \sin\ 4\,(n-n')\,t\\ &+ 0{\cdot}00000{,}02375{,}7 \sin\ 6\,(n-n')\,t\\ &+ 0{\cdot}00000{,}00015{,}1 \sin\ 8\,(n-n')\,t\\ &+ 0{\cdot}00000{,}00000{,}1 \sin 10\,(n-n')\,t;\end{aligned}$$

$$\begin{aligned}\frac{1}{r} = &\quad 1{\cdot}00090{,}73880{,}5\\ &+ 0{\cdot}00718{,}64751{,}6 \cos\ 2\,(n-n')\,t\\ &+ 0{\cdot}00004{,}58428{,}9 \cos\ 4\,(n-n')\,t\\ &+ 0{\cdot}00000{,}03268{,}6 \cos\ 6\,(n-n')\,t\\ &+ 0{\cdot}00000{,}00024{,}3 \cos\ 8\,(n-n')\,t\\ &- 0{\cdot}00000{,}00000{,}3 \cos 10\,(n-n')\,t;\end{aligned}$$

supposing that θ is expressed in the circular measure, and that the unit of distance is the mean distance in an undisturbed orbit which would be described by the Moon about the Earth in the same periodic time. In this case, if μ denote the sum of the masses of the Earth and Moon, we shall have

$$\mu = n^2.$$

The differential equation which determines z, the Moon's coordinate perpendicular to the Ecliptic, is

$$\frac{d^2z}{dt^2} + \left(\frac{\mu}{r^3} + \frac{m'}{r_1^3}\right) z = 0.$$

Now, the Sun's orbit being circular, we have $\frac{m'}{r_1^3} = n'^2$, and the only function of the Moon's coordinates which we require in order to form this equation is $\frac{1}{r^3}$.

I find that, with the above unit of distance,

$$\begin{aligned}\frac{1}{r^3} = &\quad 1{\cdot}00280{,}21783{,}115\\ &+ 0{\cdot}02159{,}98364{,}4 \cos\ 2\,(n-n')\,t\\ &+ 0{\cdot}00021{,}53273{,}9 \cos\ 4\,(n-n')\,t\\ &+ 0{\cdot}00000{,}20644{,}8 \cos\ 6\,(n-n')\,t\\ &+ 0{\cdot}00000{,}00192{,}9 \cos\ 8\,(n-n')\,t\\ &+ 0{\cdot}00000{,}00000{,}3 \cos 10\,(n-n')\,t.\end{aligned}$$

Let

$$\frac{1}{(n-n')^2}\left(\frac{\mu}{r^3} + \frac{m'}{r_1^3}\right), \quad \text{or} \quad \frac{1}{(n-n')^2}\left(\frac{n^2}{r^3} + n'^2\right), = \frac{1}{(1-m)^2}\left(\frac{1}{r^3} + m^2\right),$$

$$= q^2 + 2q_1 \cos 2\,(n-n')\,t + 2q_2 \cos 4\,(n-n')\,t + 2q_3 \cos 6\,(n-n')\,t + \&c.;$$

then we find, from the above value of $\frac{1}{r^3}$, that

$$q^2 = 1{\cdot}17804{,}44973{,}149, \quad \text{and} \quad q = 1{\cdot}08537{,}75828{,}323,$$
$$q_1 = 0{\cdot}01261{,}68354{,}6,$$
$$q_2 = 0{\cdot}00012{,}57764{,}3,$$
$$q_3 = 0{\cdot}00000{,}12059{,}0.$$

These are all the quantities necessary for finding the motion of the Moon's node, to the order which we require.

If $g\pi$ denote the angular motion of the Moon from its node in half a synodic period of the Moon, the equation so often referred to above gives

$$\cos g\pi = \cos q\pi \left\{ 1 - \frac{\pi^2 q_1^4}{32q^2(q^2-1)^2} - \frac{15q^4-35q^2+8}{256q^4(q^2-1)^4(q^2-4)}\pi^2 q_1^6 + \frac{3\pi^2 q_1^4 q_2}{32q^2(q^2-1)^2(q^2-4)} - \frac{\pi^2 q_1^2 q_2^2}{16q^2(q^2-1)(q^2-4)} \right\}$$
$$+ \sin q\pi \left\{ \frac{\pi q_1^2}{4q(q^2-1)} + \frac{15q^4-35q^2+8}{64q^3(q^2-1)^3(q^2-4)}\pi q_1^4 - \frac{\pi^3 q_1^6}{384q^3(q^2-1)^3} + \frac{105q^{10}-1155q^8+3815q^6-4705q^4+1652q^2-288}{256q^5(q^2-1)^5(q^2-4)^2(q^2-9)}\pi q_1^6 \right.$$
$$- \frac{3\pi q_1^2 q_2}{8q(q^2-1)(q^2-4)} - \frac{35q^6-280q^4+497q^2-108}{32q^3(q^2-1)^3(q^2-4)^2(q^2-9)}\pi q_1^4 q_2$$
$$+ \frac{\pi q_2^2}{4q(q^2-4)} + \frac{15q^6-110q^4+179q^2-36}{16q^3(q^2-1)^2(q^2-4)^2(q^2-9)}\pi q_1^2 q_2^2$$
$$\left. + \frac{\pi q_3^2}{4q(q^2-9)} - \frac{(3q^2-7)\pi q_1 q_2 q_3}{4q(q^2-1)(q^2-4)(q^2-9)} + \frac{5\pi q_1^3 q_3}{16q(q^2-1)(q^2-4)(q^2-9)} \right\}$$

Now, if the coefficients of cos $q\pi$ and sin $q\pi$ in this formula be converted into numbers, employing the above values of q, q_1, &c., we find

$$\cos g\pi = \cos q\pi\ [0{\cdot}99999{,}97902{,}01654] + \sin q\pi\ [0{\cdot}00064{,}77652{,}06681].$$

But, with the above value of q, we find, from Briggs' Tables,

$$\cos q\pi = -0{\cdot}96424{,}37306{,}84295$$
$$\sin q\pi = -0{\cdot}26501{,}70331{,}05484.$$

Hence

$$\cos g\pi = -0{\cdot}96441{,}51972{,}00779.$$

Whence, by the same Tables, we find that

$$g = 1{\cdot}08517{,}13927{,}46869,$$

and therefore the ratio of the Moon's motion from the node to its sidereal motion is

$$g\,(1-m) = 1{\cdot}00399{,}91618{,}46592.$$

This is the quantity ordinarily denoted by g in the Lunar Theory.

Delaunay's value of g, which agrees with that of Plana, is

$$g = 1 + \frac{3}{4}m^2 - \frac{9}{32}m^3 - \frac{273}{128}m^4 - \frac{9797}{2048}m^5 - \frac{199273}{24576}m^6 - \frac{6657733}{589824}m^7.$$

If this be converted into numbers by substituting the value of $m = 0{\cdot}0748013$, we find

$$g = 1{\cdot}00399{,}91722{,}8,$$

which differs from the true value in the eighth place of decimals.

If we take $\mathrm{m} = \dfrac{m}{1-m}$ and develop the value of g in powers of m, we find

$$g = 1 + \frac{3}{4}\mathrm{m}^2 - \frac{57}{32}\mathrm{m}^3 + \frac{123}{128}\mathrm{m}^4 - \frac{1925}{2048}\mathrm{m}^5 + \frac{25667}{24576}\mathrm{m}^6 - \frac{268309}{589824}\mathrm{m}^7;$$

and substituting the value of

$$\mathrm{m} = 0{\cdot}08084{,}89030{,}52,$$

we find

$$g = 1{\cdot}00399{,}91591{,}1,$$

which is considerably nearer the truth than the value found from the series in powers of m.

The numerical values of the successive terms of the series for $g-1$, in terms of powers of m and of m respectively, are given in the following comparative table :—

In powers of m.			In powers of m.		
m^2		·00419,64258,6	m^2		·00490,24088,4
m^3	−	11,77117,9	m^3	−	94,13416,4
m^4	−	6,67712,1	m^4		4,10574,2
m^5	−	1,12023,4	m^5	−	,32469,2
m^6	−	,14203,4	m^6		,02916,8
m^7	−	,01479,0	m^7	−	,00102,7
		·00399,91722,8			·00399,91591,1

This shows that the development in powers of m is much more advantageous than that in powers of m.

The same thing likewise holds good with respect to the value of c, which determines the motion of the perigee.

The following is a similar table, showing the numerical values

of the successive terms of Delaunay's series for $1-c$ in powers of m, and of the terms of the corresponding series in powers of m :—

In powers of m.		In powers of m.	
m^2	·00419,64258,6	m^2	·00490,24088
m^3	294,27947,8	m^3	292,31135
m^4	99,56981,8	m^4	55,37745
m^5	30,35769,9	m^5	14,37162
m^6	9,13946,6	m^6	3,49278
m^7	2,82999,6	m^7	,99062
m^8	,98356,5	m^8	,42111
m^9	,34684,2	m^9	,08515
	·00857,14945,0		·00857,29096

The true value reduced from Mr. Hill's, so as to correspond to the value of m which we have employed, is

·00857,25645.

Hence, as in the former case, the advantage of developing in powers of m is very evident.

I have found that a similar advantage results from the employment of m instead of m in the development of the co-efficients of the Moon's periodic inequalities.

On a New Term of Long Period in the Mean Motion of the Moon.

By E. Neison, Esq.

The mean motion of the Moon contains a term due to the direct action of the planet *Mars*, and possessing the argument

$$\{(n-24n''+20n''')\,t+\mathrm{E}\},$$

where, following Leverrier's nomenclature, two accents denote quantities belonging to the Earth, and three accents those belonging to the planet *Mars*. The following note is directed to determining provisionally the value of this term :—

Let $\mathrm{R}^{(''')}$ denote the disturbing function arising from the direct action of *Mars* upon the Moon. Then, as shown by Delaunay,

$$\mathrm{R}^{(''')} = m'''\left\{\frac{r^2}{\Delta^3}\left(\frac{3}{2}\cos^2\mathrm{H}-\frac{1}{2}\right)+\frac{r^3}{\Delta^4}\left(\frac{5}{2}\cos^3\mathrm{H}-\frac{3}{2}\cos\mathrm{H}\right)\right\},$$

where

Δ = geocentric distance of *Mars*,

H = geocentric angular distance between *Mars* and the Moon.

Suppose the inclinations of the Moon and planet to be neglected, which can be done without sensibly affecting the results, then

$$\cos \mathrm{H} = \frac{r'''}{\Delta} \cos (v - v''') + \frac{r''}{\Delta} \cos (v - v''),$$

whence

$$\cos^3 \mathrm{H} = \frac{1}{\Delta^3} \left\{ \left(\frac{3}{4} r'''^3 + \frac{3}{2} r''^2 r''' \right) \cos (v - v''') + \left(\frac{3}{4} r''^3 + \frac{3}{2} r'''^2 r'' \right) \cos (v - v'') \right.$$
$$\left. - \frac{3}{4} r'''^2 r'' \cos (v - 2v''' + v'') + \frac{3}{4} r''^2 r''' \cos (v - 2v'' + v''') \right\}.$$

Therefore, by substitution

$$\mathrm{R}^{(''')} = m''' r^3 \left\{ \left(\frac{15}{8} \cdot \frac{r'''^3 + 2r''' r''^2}{\Delta^7} - \frac{3}{2} \frac{r'''}{\Delta^5} \right) \cos (v - v''') - \left(\frac{15}{8} \frac{r''^3 + 2r'' r'''^2}{\Delta^7} - \frac{3}{2} \frac{r''}{\Delta^5} \right) \cos (v - v \right.$$
$$\left. + \frac{15}{8} \frac{r'' r'''}{\Delta^7} [r'' \cos (v - 2v'' + v''') - r''' \cos (v - 2v''' + v'')] + \ldots . \right.$$

Throughout only terms depending on v have been retained.

As Δ is the geocentric distance of *Mars*,

$$\Delta^{-s} = \{r'''^2 + r''^2 - 2r'' r''' \cos (v'' - v''')\}^{-\frac{s}{2}},$$

a well-known function.

Let

$$(a''')^{-s} [\mathrm{B}_{\frac{s}{2}}]^{i}_{i+k} \cos \{[in'' - (i+k) n'''] t + \mathrm{E}\}$$

be the general term of Δ^{-s}, a term which is obviously of the k-th order of the eccentricities.

Then, neglecting powers and products of the eccentricities of the Earth and *Mars*, and

$$\{r'''^3 + 2r''' r''^2\} = (a''')^3 \{(1 + 2\alpha^2 + 3e'''^2) - (3 + 2\alpha^2) e''' \cos \alpha''' + \ldots . - 4\alpha e'' \cos \alpha'' + \ldots . \},$$

$$\{r''^3 + 2r'' r'''^2\} = (a''')^3 \{(2 + \alpha^2 + 3e'''^2) \alpha - 2\alpha e''' \cos \alpha''' + \ldots . - (2 + 3\alpha^2) \alpha e'' \cos \alpha'' + \ldots . \},$$

$$\cos (v - v''') = \cos (v - n''' t - \epsilon''') + \{2e''' \sin \alpha''' + \ldots . \} \sin (v - n''' t - \epsilon'''),$$
$$\cos (v - v'') = \cos (v - n'' t - \epsilon'') + \{2e'' \sin \alpha'' + \ldots . \} \sin (v - n'' t - \epsilon''),$$

$$\cos (v - 2v''' + v'') = \cos (v + [n'' - 2n'''] t + \epsilon'' - 2\epsilon''') + \{4e''' \sin \alpha''' - 2e'' \sin \alpha'' + \ldots . \} \sin (v + [n'' - 2n'''] t + \epsilon'' - 2\epsilon'''),$$

$$\cos (v - 2v'' + v''') = \cos (v - [2n'' - n'''] t - 2\epsilon'' + \epsilon''') + \{4e'' \sin \alpha'' - 2e''' \sin \alpha''' + \ldots . \} \sin (v - [2n'' - n'''] t + 2\epsilon'' - \epsilon'''),$$

where, for convenience, $\frac{a''}{a'''}$ has been denoted by α, as usual, and a'' and a''' denote the mean anomalies of the Earth and *Mars*.

Further, if σ be the ratio of the masses of the Sun and *Mars*, and $m = \frac{n''}{n}$,

$$m'' = \sigma m^2 \left(\frac{a'''}{a}\right)^3.$$

Substituting these values in the expression for $R^{(''')}$, it becomes

$$R^{(''')} = \sigma m^2 . a^4 . \left(\frac{a}{a'''}\right) . \frac{r^3}{a^4} . \left\{ \frac{15}{16} \left([1 + 2\alpha^2 + 3e'''^2] [B_{\frac{7}{2}}]^{24}_{21} - [2 + \alpha^2 + 3e'''^2] \alpha [B_{\frac{7}{2}}]^{23}_{20} \right.\right.$$

$$+ \alpha^2 [B_{\frac{7}{2}}]^{22}_{19} - \alpha [B_{\frac{7}{2}}]^{25}_{22}$$

$$- \frac{1}{2} (1 - 2\alpha^2) e''' [B_{\frac{7}{2}}]^{24}_{22} + \alpha e''' [B_{\frac{7}{2}}]^{23}_{21} - \frac{3}{2} e''' \alpha^2 [B_{\frac{7}{2}}]^{22}_{20} - e''' \alpha [B_{\frac{7}{2}}]^{25}_{23}$$

$$- 2\alpha e'' [B_{\frac{7}{2}}]^{23}_{21} - \frac{1}{2} (2 - \alpha^2) \alpha e'' [B_{\frac{7}{2}}]^{22}_{20} + \frac{3}{2} \alpha e'' [B_{\frac{7}{2}}]^{24}_{22} + \alpha e'' [B_{\frac{7}{2}}]^{21}_{19}$$

$$\left. + \frac{4}{5} [B_{\frac{5}{2}}]^{23}_{20} \alpha - \frac{4}{5} [B_{\frac{5}{2}}]^{24}_{21} \right) \cos (v - [24n'' - 20n'''] t - E) + \ldots .$$

The products of the eccentricities of *Mars* and the Earth, with the coefficients $[B_{\frac{5}{2}}]^i_{i+k}$, have been neglected because they will be very small.

In this expression, r^3 and v can be directly replaced by a'''^3 and $nt + \varepsilon$, as the terms depending on the eccentricity of the Moon, are not required. Then, putting the above coefficient in brackets equal to (R), we have

$$R^{(''')} = \sigma m^2 . a^4 . \left(\frac{a}{a'''}\right) . \frac{1}{a} . (R) \cos \{[n - 24n'' + 20n'''] t + \epsilon - E\}.$$

Substituting this value in the equation for δn, since

$$\delta n = -3 \iint a n^2 \left(\frac{dR}{d\epsilon}\right) dt^2,$$

the inequality in the mean motion of the Moon will be

$$\delta n = -\sigma m^2 . a^4 . \left(\frac{a}{a'''}\right) . \left(\frac{n}{n - 24n'' + 20n'''}\right)^2 . 3 (R) . \sin \{[n - 24n'' + 20n'''] t + \epsilon - E\}.$$

Adopting Hansen's value for the mean motion of the Moon (*Tables de la Lune*) and Leverrier's values for the mean motions of *Mars* and the Earth (*Annales de l'Observatoire*), then

n	= 17	325	594″·0
$24n'' - 20n'''$	= 17	322	447″·5
$n - 24n'' + 20n'''$	=	3	146″·5

The motion of the perihelions of *Mars* and the Earth may be neglected in what follows, though tending to slightly decrease the results.

Suppose σ, or the ratio of the masses of *Mars* and the Sun, to be taken as $\frac{1}{3{,}000{,}000}$, and assume $\frac{a}{a''} = 0{\cdot}0025856$, corresponding to a solar parallax of $8''{\cdot}85$; then

$$\sigma m^2 a^4 . \left(\frac{a}{a''}\right) . \left(\frac{n}{n - 24n'' + 20n'''}\right)^2 . 3 = 12''{\cdot}5150 . \log = 1{\cdot}09753.$$

The coefficients $[B_{\frac{1}{2}}]^i_{i+k}$ can be readily calculated by making use of the developments given in either Pontécoulant's *Système du Monde*, or Delaunay's memoir in the *Conn. des Temps*, 1863.

On substituting the proper values in the above expression for (R), the first four terms entirely destroy each other, and with them vanishes the largest part of the coefficient of the term. The terms depending on the eccentricity of *Mars* yield therefore the principal part of the coefficient, those depending on the eccentricity of the Earth being decreased by its smallness. The last two terms destroy each other. The complete value is therefore

$$\begin{aligned}
&+ 5{\cdot}90 \sin \{[n - 24n'' + 20n'''] t + \epsilon - 24\epsilon'' + 20\epsilon''' + 3\varpi'''\} \\
&- 2{\cdot}33 \sin \{[n - 24n'' + 20n'''] t + \epsilon - 24\epsilon'' + 20\epsilon''' + \varpi'' + 2\varpi'''\} \\
&+ 0{\cdot}10 \sin \{[n - 24n'' + 20n'''] t + \epsilon - 24\epsilon'' + 20\epsilon''' + 2\varpi'' + \varpi'''\} \\
&+ 0{\cdot}04 \sin \{[n - 24n'' + 20n'''] t + \epsilon - 24\epsilon'' + 20\epsilon''' + 3\varpi''\}
\end{aligned}$$

or

$$\delta n = + 7''{\cdot}55 \sin \{[n - 24n'' + 20n'''] t + \epsilon - 24\epsilon'' + 20\epsilon''' + 284^\circ\ 14'\}.$$

Writing it as a term increasing with the time, then

$$\delta n = \qquad \sin \{53''{\cdot}2\ (T - 1807{\cdot}6)\},$$

where T is the year for which the value of the inequality is required. The inequality has therefore a period of 406·0 years.

In the *Monthly Notices* for November 1873, there is a paper by Sir George Airy bearing on the lunar theory. The Astronomer Royal there remarks:—"It appears, therefore, that after applying the best correction that we are able to give to the assumed mean longitude and mean motion, there still remains a series of unexplained discordances, varying from $-6''{\cdot}79$ to $+4''{\cdot}93$. And each of the discordances here exhibited is based on about 440 observations; these observations are all reduced by the same system of clock stars and other elements (Bessel's in the *Tabulæ Regiomontanæ*), and the tabular places are all computed by the same theory (Plana's with Damoiseau's epochs).

"I conceive it to be totally impossible that a complete and correct theory can leave such large and systematic discordances. And I express my opinion that there is still some serious defect in the lunar theory." (*Monthly Notices*, xxxiv., p. 5.)

The Astronomer Royal has tabulated these residual errors for groups of about $4\frac{1}{2}$ years, between 1750 and 1851. It was thus easy to see how far the newly discovered term reduces or augments these residual discordances. It was therefore gratifying to find that for the period between 1780 and 1851 it completely accounts for them. For this period the mean of the outstanding positive errors is reduced to about $0''\cdot7$, and the mean of the outstanding negative errors is reduced to about $0''\cdot6$. It does not account so well for the residual discordances between 1765 and 1780, and fails to account for the errors in the period 1750–1765. I have, however, discovered a minor term which will partially account for the errors in these earlier observations between 1750 and 1770.

From the nature of the new term it is obvious that the value which has been deduced for it in the present paper is at best merely provisional. It will require most careful revision, and the higher powers of the disturbing forces must be taken into account. This will involve some labour, because, owing to the great eccentricity of the orbit of *Mars*, the convergency of the series which it involves is slow. It is probable that when the complete value of the term is ascertained, it will be found to be slightly smaller than that depending on the first power of the disturbing forces. Under these conditions it would still better represent the observations. The existence of this term is so strongly supported by observation, from the manner in which it removes the discordances between theory and observation detected by Sir G. Airy, that I thought it better to publish it in its present form, rather than defer this for the considerable period which may elapse before I am able to verify these results.

I take this opportunity to announce that I have discovered other terms in the mean motion of the Moon, arising from the direct action of the planets, and having sensible coefficients. I hope to be able to bring these before the Society in a short period. One of these, having the comparatively short period of 60 years, appears to be strongly indicated by observation.

London, Nov. 2, 1877.

On Three Small Inequalities in the Mean Motion of the Earth, and an Inequality in the Mean Motion of Mars. By E. Neison, Esq.

Whilst engaged on some investigations connected with the perturbations in the motion of the Moon produced by the action of the planets, I came across several terms of long period in the

mean motion of the Earth which it appeared might possibly have a sensible value. These terms depend on the second power of the disturbing force. Hitherto the only two terms of long period of this character which have been made known are the two terms discovered by Leverrier, and embodied in his solar tables. (*Annales de l'Observatoire*, tome iv.) These terms are, adopting Leverrier's notation,

$$6''{\cdot}410 \sin\{[4n'' + 3n^{\text{IV}} - 8n'''] t + \text{A}\}, \qquad 0''{\cdot}292 \sin\{[7n'' - 3n' - 4n'''] t + \text{A}_1\},$$

the first having a period of 1,800 years and the second a period of 300 years.

The first new term depends on three times the mean motion of the Earth, plus three times the mean motion of *Jupiter*, minus twice the mean motion of *Venus*. In fact $[3n'' - 2n' + 3n^{\text{IV}}] = 2419''$ only, so that the term has a period of 530 years, which might give it a sensible value, although multiplied by the fourth power of the eccentricity of *Jupiter*. On computing its value, it was found, however, that all the principal terms destroy each other, so that the largest coefficient does not amount to $0''{\cdot}01$. There is another term of still longer period, namely that depending on the relation $[6n'' - 5n' + 4n'''] = 1140''$, but this also will be probably entirely insensible.

The argument of the second term depends on the mean motion of the Earth, plus twice the mean motion of *Saturn*, minus twice the mean motion of *Mars*. As $[n'' + 2n^{\text{V}} - 2n'''] = 5868''$, and the term is of the first order of the eccentricities, it might have yielded a term with a sensible coefficient. On calculating the different terms, the only sensible one was found to be

$$+0''{\cdot}0178 \sin\{(n'' - 2n''' + 2n^{\text{V}}) t + \epsilon'' - 2\epsilon''' + 2\epsilon^{\text{V}} + \varpi'''\}.$$

This term, although larger than many retained by Leverrier in his tables of the Sun, is insignificant. A similar but larger term must exist in the mean motion of *Mars*, and by calculating its value it was found to be

$$-0''{\cdot}1275 \sin\{(2n''' - n'' - 2n^{\text{V}}) t + 2\epsilon''' - \epsilon'' - 2\epsilon^{\text{V}} + \varpi''\}.$$

It has a period of 220·9 years, and, being capable of altering the geocentric longitude of *Mars* by nearly half a second of arc, deserves some attention.

The third term depends on ten times the mean motion of the Earth, minus six times the mean motion of *Venus*, and three times the mean motion of *Jupiter*, and is therefore analogous to the very important term discovered by Leverrier, and depending on the mean motion of the Earth, *Mars*, and *Jupiter*. Inasmuch as $[10n'' - 6n' - 3n^{\text{IV}}] = -7846''$, the term has a period of 165 years. The principal terms mutually destroy each other, so that the coefficient is not one-tenth of what might have been expected.

The main outstanding terms are the following:—

$$+\{0''\cdot0811-0''\cdot1578 = -0''\cdot0767\}\sin\{(10n''-6n'-3n^{IV})\,t+10\epsilon''-6\epsilon'-3\epsilon^{IV}-\varpi''\}$$

$$-\{0''\cdot0273-0''\cdot0384 = -0''\cdot0111\}\sin\{(10n''-6n'-3n^{IV})\,t+10\epsilon''-6\epsilon'-3\epsilon^{IV}-\varpi'\}$$

$$+\{0''\cdot0080-0''\cdot0171 = -0''\cdot0091\}\sin\{(10n''-6n'-3n^{IV})\,t+10\epsilon''-6\epsilon'-3\epsilon^{IV}+\varpi^{IV}-2\varpi''\}.$$

$$+\{-0''\cdot0057\}\sin\{(10n''-6n'-3n^{IV})\,t+10\epsilon''-6\epsilon'-3\epsilon^{IV}+\varpi^{IV}-\varpi''-\varpi'\}.$$

There is a peculiarity about this term which I am in hopes of examining. According to Leverrier the mean motion of *Neptune* is equal to $7872''\cdot7$. Therefore the term just considered in the mean motion of the Earth will give rise to another term of the form

$$\{10n''-6n'-3n^{IV}-n^{VII}\},\ =-26''.$$

This will be a term independent of the eccentricities, and of the third power of the disturbing forces, and with an immensely long period of 50,000 years, or nearly twice the period of the revolution of the Earth's perihelion. It is therefore very probable that this term possesses a comparatively considerable coefficient. It is true, from its immense length of period, the term is without importance as far as tables of the position of the Earth is concerned, but it possesses a scientific interest. A slight change in the value of the mean motion of *Neptune* would convert this term into a secular term, by making

$$\{[10n''+2\varpi''-6n'-3n^{IV}-n^{VII}]\}=0.$$

My principal reason for communicating these results is to let it be known that they have been examined. Hansen calculated many terms of this nature in the theory of the Earth, but he has nowhere stated what terms he so examined. This is to be regretted, as it leaves this fruitless and laborious work to be performed again by anyone traversing the same ground. Similarly, had Hansen and Delaunay published a list of the terms produced by the planets in the motion of the Moon which they had examined, it would have materially lightened the labour of anyone endeavouring to discover the missing terms of long period in the motion of the Moon.

Oct. 29, 1877.

The Satellite of Neptune. By J. W. Ward, Belfast.

The following observations were all made without any knowledge of the position angles or distances by Ephemeris, which was *afterwards* consulted. On the whole I do not think that this satellite is more difficult than the two outer satellites of *Uranus* as observed in the spring of 1876. The points were glimpsed by averted vision.

Telescope 4·3 in., Wray, power 175.

Date. 1877.	Local M.T. of Obs.	Estimated P. Angle.	P. Angle Ephem. at 11 hours G.M.T.	Dist. Ephem.	Estimated Dist.	
		°	°	″	″	
	±	±			±	
Oct. 16	12½ H.	75	86	7·45	10	Moonlight.
„ 17	11 „	45	44	16·7	15	do.
„ 27	12 „	170	194	10·5	10	Another point: P. 300°; D. 15″ ±
„ 29	12 „	40	40·2	17·0	15	
„ 30	11 „	350	10·6	9·8	10	
Nov. 6	11¼ „	240	241·9	11·4	10	

Coggia's Comet, 1877.

(*Communicated by Prof. Pritchard, University Observatory, Oxford.*)

From an observation at Marseilles, on September 14, and two others at Oxford on October 6 and 31, the following elements were computed :—

T	Sept. 11·40830 G.M.T.		
	°	′	″
π	107	37	41·2
Ω	250	58	48·9
i	77	42	26·9
log q	0·1977141		

Motion retrograde.

The middle observation is represented within the errors—

		″
C−O	$dl \cos b$	+7
	db	−3

Ephemeris of Coggia's Comet for Greenwich Mean Midnight.

	R.A. h	m	s	N.P.D. °	′	log Δ
Nov. 12	6	5	45	73	10·8	9·9634
16	5	46	0	77	41·8	9·9562
20	5	25	56	82	20·6	9·9562
24	5	6	14	86	54·7	9·9636
28	4	47	23	91	12·1	9·9778
Dec. 2	4	29	49	95	3·9	9·9978
6	4	13	49	98	25·3	0·0220

The computations were made by Mr. W. Plummer.

Oxford, Nov. 9, 1877.